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Report 2379

DESIGN AND INTEGRATION OF AN ELECTRIC TRANSMISSION IN A 300-hp MARINE CORPS AMPHIBIOUS VEHICLE

by
Carl J. Heise
and
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April 1983

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 2379	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DESIGN AND INTEGRATION OF AN ELECTRIC TRANSMISSION IN A 300-hp MARINE CORPS AMPHIBIOUS VEHICLE		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Carl J. Heise Michael A. Mando		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Electrical Equipment Div, DRDME-EAM Engineer Service Support Lab MERADCOM, Ft. Belvoir, VA 22060		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Marine Corps Programs Office; David W. Taylor Naval Ship Research and Development Center, Code 1129; Bethesda, MD 20084		12. REPORT DATE April 1983 13. NUMBER OF PAGES 71
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Electric Propulsion
Electric Power Generation
Motor Control
Reduction Gears
Tracked Vehicle Performance
Propulsion System Control

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A design for a d.c. electric drive for the M113A2 based on available state-of-the-art components is proposed. The proposed electric drive has a specific weight of about 9 lb/hp. Efforts were made to make this estimated weight as realistic as possible; auxiliary components such as field supply, cooling system, braking resistor, and controls account for 1 lb/hp and a miscellaneous category adds another 0.44 lb/hp.

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- As proposed the vehicle design for the M113A2 meets the performance requirements of 40 mi/h and a maximum sprocket torque of 17,000 ft-lb. It has no separate water propulsion system; however, a water propulsion system powered by the alternator can be added without disturbing the land propulsion system.

SUMMARY

A design for an electric drive for the M113A2 based on available state-of-the-art components is proposed. The proposed electric drive has a specific weight of about 9 lb/hp. Efforts were made to make this estimated weight as realistic as possible; auxiliary components such as field supply, cooling system, braking resistor, and controls account for 1 lb/hp and miscellaneous items add another 0.44 lb/hp.

As proposed, the vehicle design for the M113A2 meets the standard military requirements and is capable of 40 mi/h and a maximum sprocket torque of 17,000 ft-lb. It has no separate water propulsion system; however, a water propulsion system powered by the alternator can be added without disturbing the land propulsion system.

The drive train consists of a Detroit Diesel 6V-53T engine, a Westinghouse 500-kVA alternator, an air-cooled rectifier, and, on each side, a GE 90-hp d.c. drive motor driving the track through a Funk two-speed gearbox which is coupled to the existing final drive. The field excitation for the drive motors is supplied by a Bendix 48-V brushless d.c. generator driven by the vehicle engine.

The layout of the major components is similar to the standard M113. The engine remains in the same place and drives the 500-kVA alternator with a belt. The alternator is mounted in place of the existing transmission. The two drive motors and gearboxes will replace the existing differential.

The operator controls appear to be conventional to the operator. They are accelerator, brake, shift, and steering wheel. However, control is accomplished by the use of a micro-computer. Operator inputs, as well as other inputs from the vehicle, are fed into the computer which then sets the proper engine speed, generator voltage, motor field, etc. The vehicle is capable of regenerative steering and has both electric resistive braking and hydraulic disc brakes.

Specific weight reduction opportunities are identified that could reduce the weight of the proposed system by 1.1 lb/hp. Additional areas of technological development that would be likely to yield further specific weight reduction are discussed.

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PREFACE

The authors appreciate valuable guidance by the following personnel of the Electrical Equipment Division, Electrical Power Laboratory:

Dr. Larry I. Amstutz.
Dr. James H. Ferrick.
Mr. Anthony J. Smith.
Mr. Gerald J. Sullivan.
Dr. David W. Lee.

Appreciation is also due Mr. Mark Poppe for making illustrations and Ms. Dayle Smith for typing.

Estimates of size, weight, and volume for the drive-motor gears were calculated by Mr. David P. Guimand, DTNSRDC, Annapolis, Maryland.

Thanks to Mr. Mark Rice, David Taylor Naval Ship R&D Center Carderock Laboratory, Bethesda, Maryland, for initiation and support of this study.

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DESIGN AND INTEGRATION OF AN ELECTRIC TRANSMISSION IN A 300-HORSEPOWER MARINE CORPS AMPHIBIOUS VEHICLE

I. INTRODUCTION

1. Background. This report summarizes a MERADCOM preliminary design of an electric-drive demonstrator using an M113A2 as a surrogate for a new Marine Corps Amphibian. The work was funded by the Marine Corps Programs Office at the David W. Taylor Naval Ship Research and Development Center as a part of their exploration of alternative drive trains for future amphibious vehicles.

2. Scope. It is worthwhile to discuss the scope of this effort and its relation to an earlier competitive solicitation for the development of an electric-drive train. Our effort was relatively compressed in time and limited in the scale of the investigations. Considerable emphasis has been placed on experience, engineering judgment, and even intuition in arriving quickly at a design we believe will meet both the Marine Corps near-term goal for demonstrating the performance of an electric drive and offer significant opportunity for performance growth. At the outset this investigation was limited to a.c. generators and d.c. drive motors. Furthermore, the water propulsion aspects of the competitive statement of work has been eliminated from consideration, although such a requirement is fully compatible with the approaches considered.

The work was done during the fall of 1982. Our thrust was to locate state-of-the-art components and to combine them into an electric-drive design that would meet the Marine Corps goals for performance, light weight, and low space claim and that could be built and tested in the immediate future at a moderate cost. The effort was structured this way to emphasize development of electric-drive-train technology as a whole. The initial demonstration would establish the capability of satisfying the Marine Corps near-term goals with an electric drive. It would also provide information needed to guide the electric-drive technology development needed to realize potential improvement in performance.

II. INVESTIGATION

3. Requirements. The initial requirements for the M113 vehicle were as follows:

Gross Vehicle Weight: 28,000 lb.

Tractive Effort to Weight Ratio: 0.89 (25,000-lb tractive effort).

Engine: 6V-53T, 300 bhp @ 2800 r/min.

Rolling Resistance: Assume 1200 lb constant.

Gradability: 60% longitudinal; 40% transverse.

Maximum Speed: 45 mi/h on land (788 r/min on a 9.6-in. rolling radius).
10 mi/h in water (4500 lb thrust).

Sprocket Torque: 10,000 ft-lb per side.

Steering: Fully variable, fully regenerative.

Braking: 16 ft/s² dynamic, static for 60% grade.

Acceleration: 0-20 mi/h in 5 s.
0-45 mi/h in 45 s.

Life Cycle: 2400 h at specified duty cycle.

Weight: 3000 lb or less.

Efficiency: 200$^+$ sprocket horsepower available over 90% of the speed torque range.

Environmental: -25° to +124° F; 10% to 100% humidity.

Based on observations made at the GE, Dalton, Massachusetts, Test Track, instructions from the Marine Corps were to decrease sprocket torque and maximum speed to 8500 ft-lb per side and 40 mi/h for purposes of this investigation.

In addition, the water propulsion requirement was eliminated for this investigation.

Four of the most severe operating conditions were added to the requirements as specific cases. These are:

a. Low Speed, Straight Ahead, 60% Grade.

Left Sprocket		Right Sprocket	
+40 r/min +6200 ft-lb	+47 hp	+40 r/min +6200 ft-lb	+47 hp

b. **High Speed, Straight Ahead, 0% Grade.**

Left Sprocket		Right Sprocket	
+750 r/min	+120 hp	+750 r/min	+120 hp
+850 ft-lb		+850 ft-lb	

c. **Low Speed, Clockwise Pivot Turn in Soft Soil, 0% Grade.**

Left Sprocket		Right Sprocket	
+10 r/min	+17 hp	-10 r/min	+17 hp
+9000 ft-lb		-9000 ft-lb	

d. **High Speed, Clockwise Turn, 0% Grade.**

Left Sprocket		Right Sprocket	
+770 r/min	+293 hp	+740 r/min	-113 hp
+2000 ft-lb		-800 ft-lb	

4. **Drives Considered.** Two systems will be discussed, one using three motors per side driving through a combining gear and the other using one motor per side with the two motors mounted one above the other in the front center of the vehicle in place of the differential steering unit. The two systems are shown in Figures 1, 2, and 3.

5. **Description of System.** All major components of the electric-drive system and their interconnections are shown in Figure 4. The system consists of a diesel engine driving, through a speed increaser, one alternator. The output of the alternator is rectified in a three-phase full-wave rectifier, and the d.c. output of the rectifier is fed to the motors via a two-position switch such that the motors can be connected to the braking grid. The broken lines from components to the control box denote control lines for the most important control functions. These functions are engine speed, alternator field current, motor field currents, gear shift, and dynamic braking. All control power is supplied by the battery and battery charger, and motor field power is supplied by a small generator which is belt-driven from the engine.

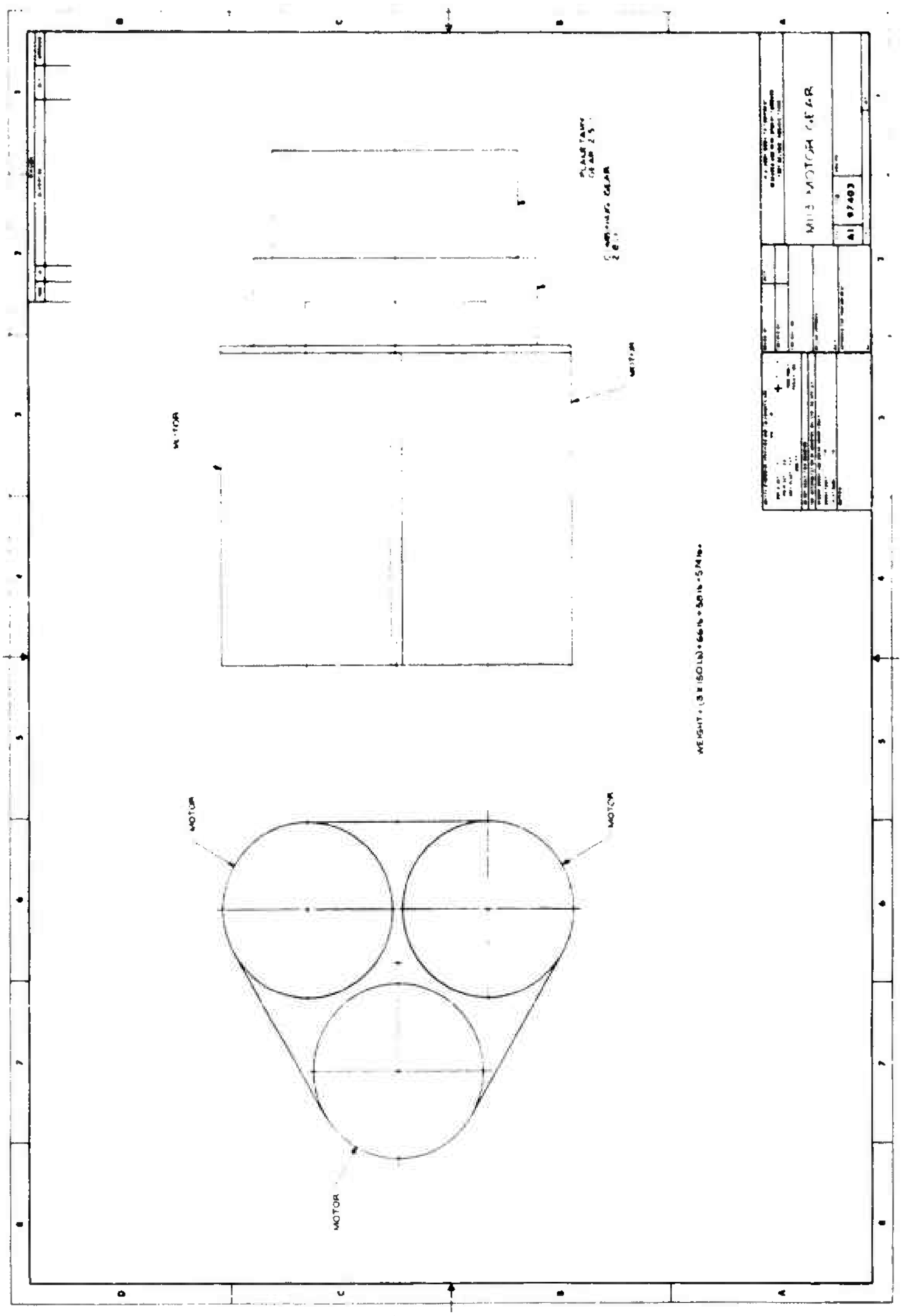


Figure 1. Three-motor-per-side installation.

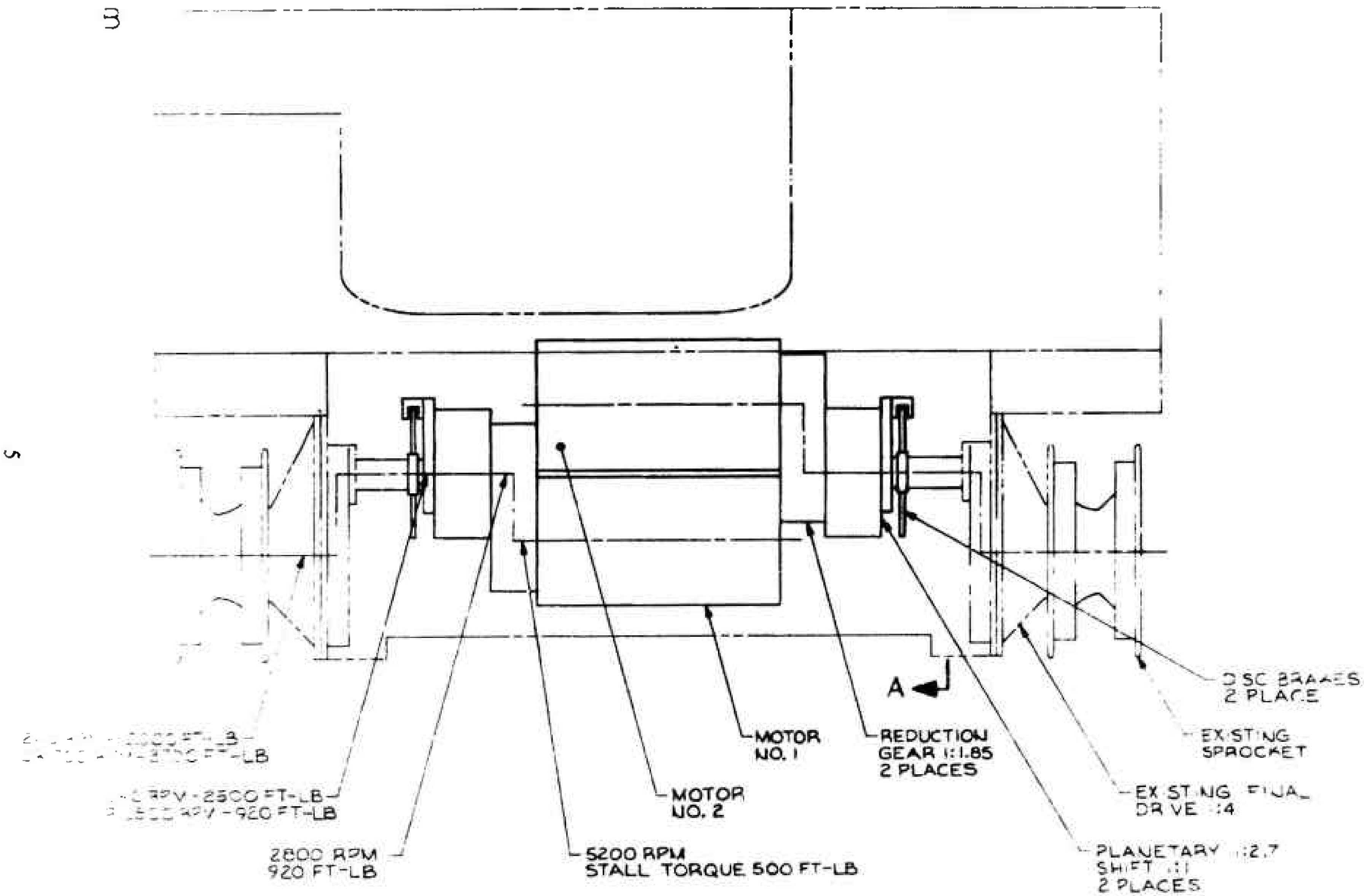


Figure 2. Two-motor electric-drive system.

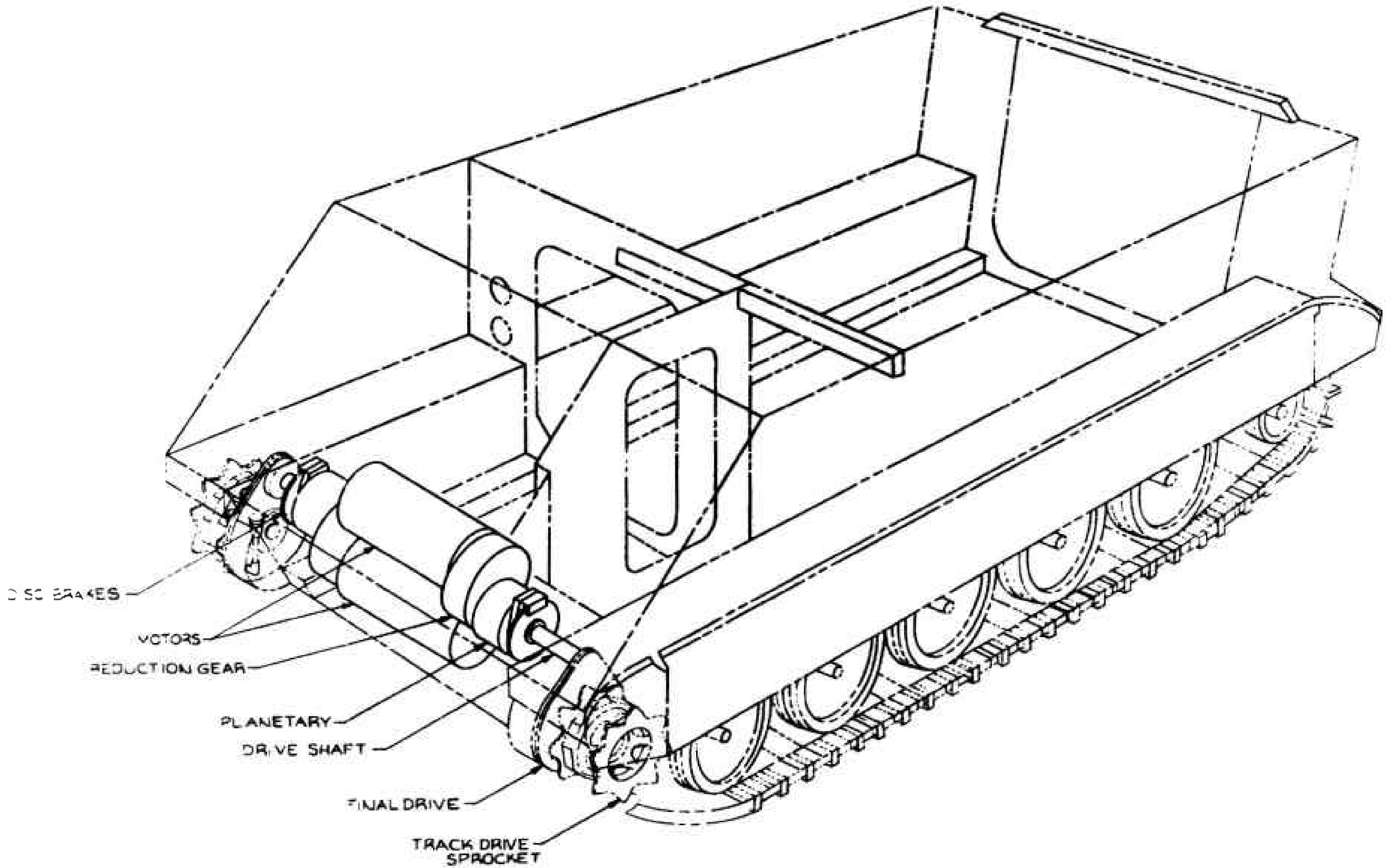


Figure 3. Two-motor installation in an M113A2 APC.

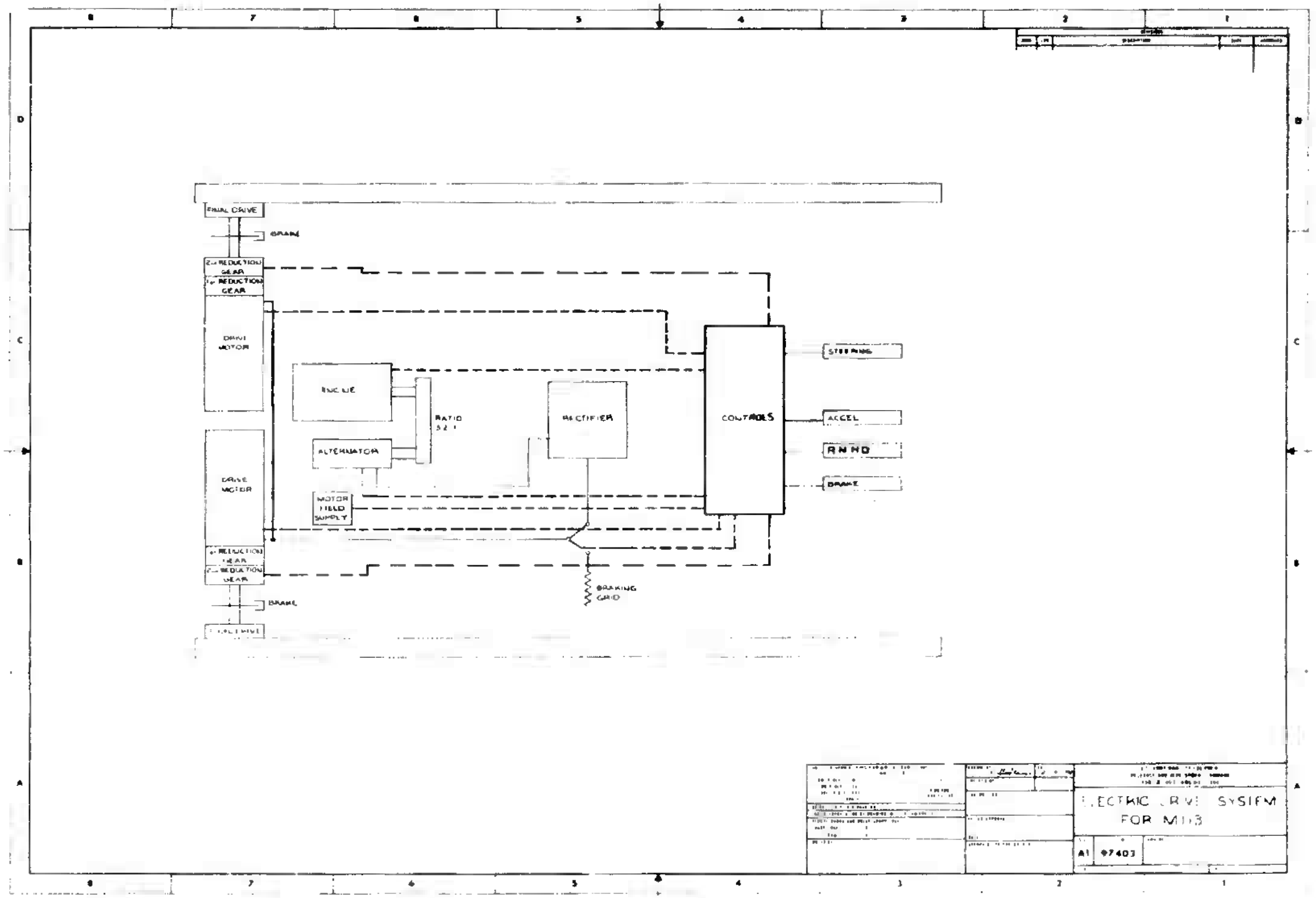


Figure 4. Drive system schematic.

6. Description of Components.

a. Engine. The engine is a Detroit Diesel, 6V-53T, capable of delivering 300 bhp at 2800 r/min.

b. Alternator. In order to demonstrate electric drive for a tracked vehicle at reasonable cost, great emphasis has been placed on selecting components on hand or in regular production. For the safety of personnel it is desirable to keep the system voltage at a level as low as possible. However, the lower the voltage, the higher the current will be. In both designs to be discussed, maximum motor current will be 1000 A or a total of 2000 A in order to get 17,000-ft-lb total sprocket torque. For three motors per side maximum voltage will be 300 V, and for one motor per side it will be 120 V.

The alternator selected for the demonstrator is a 500-kVA Westinghouse alternator of the same type as that used in the M113 demonstrator made by the FMC Corporation. This alternator is on hand at MERADCOM, and recent tests at MERADCOM show that it is capable of delivering 2000 A at 4000 r/min, which corresponds to 1250 r/min engine speed. The alternator will be belt-driven as in the FMC demonstrator (SAE Paper No. 690442, May 1969). The weight of this alternator is 430 lb.

For future electric-drive systems, a weight saving of 280 lb can be realized by using two Bendix type 28B329-1 brushless alternators. This alternator is an oil-cooled 150-kVA machine (see Appendix A for description). For this application the machine could be wound for half the usual voltage, which will double its usual current capability. The two alternators would be driven through a speed-increasing combining gear box and mechanically arranged so that their phase voltages will add arithmetically. The system could still be used as a 400-Hz mobile electric power plant with the standard output of 120/208 V, when the phases in the two machines are series-connected.

c. Rectifier. The rectifier is a three-phase full-wave bridge and there are three choices of units:

(1) Forced-air-cooled. The Westinghouse PDA7B7S016 in a three-phase full-wave bridge arrangement can supply in excess of 2000 A if 60° C or less inlet air is delivered over the heat sink at 500 lin ft/min. A straightforward arrangement of these assemblies would be about 18 in. wide by 15 in. high by 7 in. deep and would weigh 50 lb. Required airflow would be about 400 ft³/min. Air ducts and cooling fans will be required in addition.

(2) Natural Convection Cooling. The Westinghouse PDA9R9G022 is a typical natural convection air-cooled assembly. These assemblies are rated at 2000 A in ambient air at 55° C. An arrangement of these assemblies would occupy a space 32 in. wide by 18 in. high by 7 in. deep and would weigh about 110 lb.

(3) **Water-cooled.** Westinghouse PDW7R720 assemblies are sufficient to deliver in excess of 3000 A with a cooling water flow of 1 gal/min per assembly (3 gal/min total) at 40° C inlet temperature. The basic assembly would occupy a space 18 in. wide by 12 in. high by 6 in. deep and would weigh about 25 lb.

A modified structure could be reduced to 18 in. by 9 in. by 6 in. A coolant distribution manifold, pump, heat exchanger, and fan (or flowing air) are also required. These, with the coolant, would add an additional 30 lb to the rectifier system weight.

A natural convection unit is recommended for the demonstrator for simplicity.

d. Drive Motors. The first approach was to use three GE model 5BY401A5 motors per side, mainly due to MERADCOM's experience with this motor and because five were on hand. The motor is rated 40 hp, 8000 r/min, 96 V, 345 A continuous duty. A series of tests performed in 1969 at the GE plant, Erie, Pennsylvania, established short time ratings. Results of the GE tests show that the motor is capable of 100-ft-lb shaft torque for 1 minute (Appendix B). To get 8500-ft-lb sprocket torque from a three-motor drive assembly, a total gear ratio of 28:1 is required. It was decided to obtain this ratio with a 2.8:1 combining gear for the three motors, a 2.5:1 planetary gear which can be shifted to a 1:1 ratio, and the present 4:1 final drive. Estimates of size, weight, and volume for the gear calculated by David P. Guimand are in Appendix C, GEAR DESIGN CALCULATIONS. Estimated size and weight of one unit consisting of three motors and the gears will then be 26.4 in. long, maximum width 18.6 in., and total weight 574 lb (see Figure 1). When we contacted GE, we learned that the BY401 motor is no longer in regular production but could still be manufactured at substantial cost. However, a new line of d.c. motors for electric cars and forklift trucks is now being manufactured. One of these motors, the BT2378, was selected for a final design. This motor is a 90-hp, 5200-r/min, 120-V, 611-A machine capable of 500-ft-lb shaft torque for 10 min and 120-hp for 30 min from a cold start. Computer runs were performed at GE for eight different shunt field voltages giving shaft torque, revolutions per minute, horsepower, and efficiency as a function of armature current (Appendix D). Using these data, the vehicle performance can be estimated.

Several distinct advantages are obtained by using this motor compared to the BY401 motor: efficiency is higher, 91.6 percent compared to 86.2 percent; maximum voltage is 120 V, where 300 V would be required for three BY401s in series; mounting is more easily accomplished; and there will be more room for the brakes. Figures 2 and 3 show the mounting of the two motors and associated gears. An additional advantage when the arrangement shown is used is that the end bells of the two motors and the housing of the first reduction gear can be made one casting and thus contribute to a very solid unit.

The total gear ratio will in this case be 20:1 in low and 7.1:1 in high gear. Total weight per side for motor and gears will be 675 lb. based on 180 lb for gears estimated by Funk Manufacturing Company. GE was contacted for an estimate of cost and delivery time and both are very reasonable. Bendix was also contacted but only for the small motor similar to the GE BY 101: they quoted a substantial cost for development and delivery of six motors (see Appendix A).

Excitation power for the motors will be delivered from a brushless d.c. generator. This generator is a type 30B119-9 machine presently being manufactured by Bendix: this generator must be modified to produce an output of 48 V and 200 A when driven at 4000 to 10,000 r/min. The weight of the generator is 15 lb (see Appendix F for descriptions).

III. DISCUSSION

7. Vehicle Performance and Contol. Calculated vehicle performance is shown in Figure 5 and is derived from the computer runs for the motor and short time ratings for the alternator. With 270 hp available from the engine and an estimated efficiency of 69 percent to 75 percent (the low efficiency is at low speed only). 200 hp can be delivered to the tracks from approximately 7 mi/h to 40 mi/h. but time will be limited to 30 minutes. Assuming 88 percent efficiency of the gears. 160 hp can be delivered continuously above 8 mi/h.

Control of vehicle speed is accomplished by control of engine speed, alternator field current, motor field current, and gear box ratio. When the vehicle is started from a dead stop, three things must happen simultaneously to obtain sufficient motor torque to get it rolling. These are: increase of motor field current, increase of engine speed, and increase of alternator field current to generate enough voltage to produce a motor armature current which, in combination with the motor field, will create the required motor torque.

As an example, if maximum sprocket torque of 17,000 ft-lb is required, the motor field voltage must be increased to 48 V resulting in a field current of approximately 100 A, engine speed must be increased to 1250 r/min which will increase the alternator speed to 4000 r/min and in combination with increasing the alternator field current to 5.2 A, will result in 1000 A of armature current in each of the two motors. The above-mentioned numbers are the result of actual testing performed at MERADCOM with the 500-kVA alternator using a fixed resistor to simulate initial motor load (see Appendix F). Referring to the GE computer run (Appendix D) for 48 V on the motor field and 1000 A armature current, the motor torque will be 433 ft-lb and the total result in low gear will then be 433 ft-lb x 20 ratio x 2 tracks = 17,400 ft-lb. After this initial startup, increase in speed is accomplished by decreasing motor field voltage and increasing alternator voltage output: this will necessitate an increase of the engine speed.

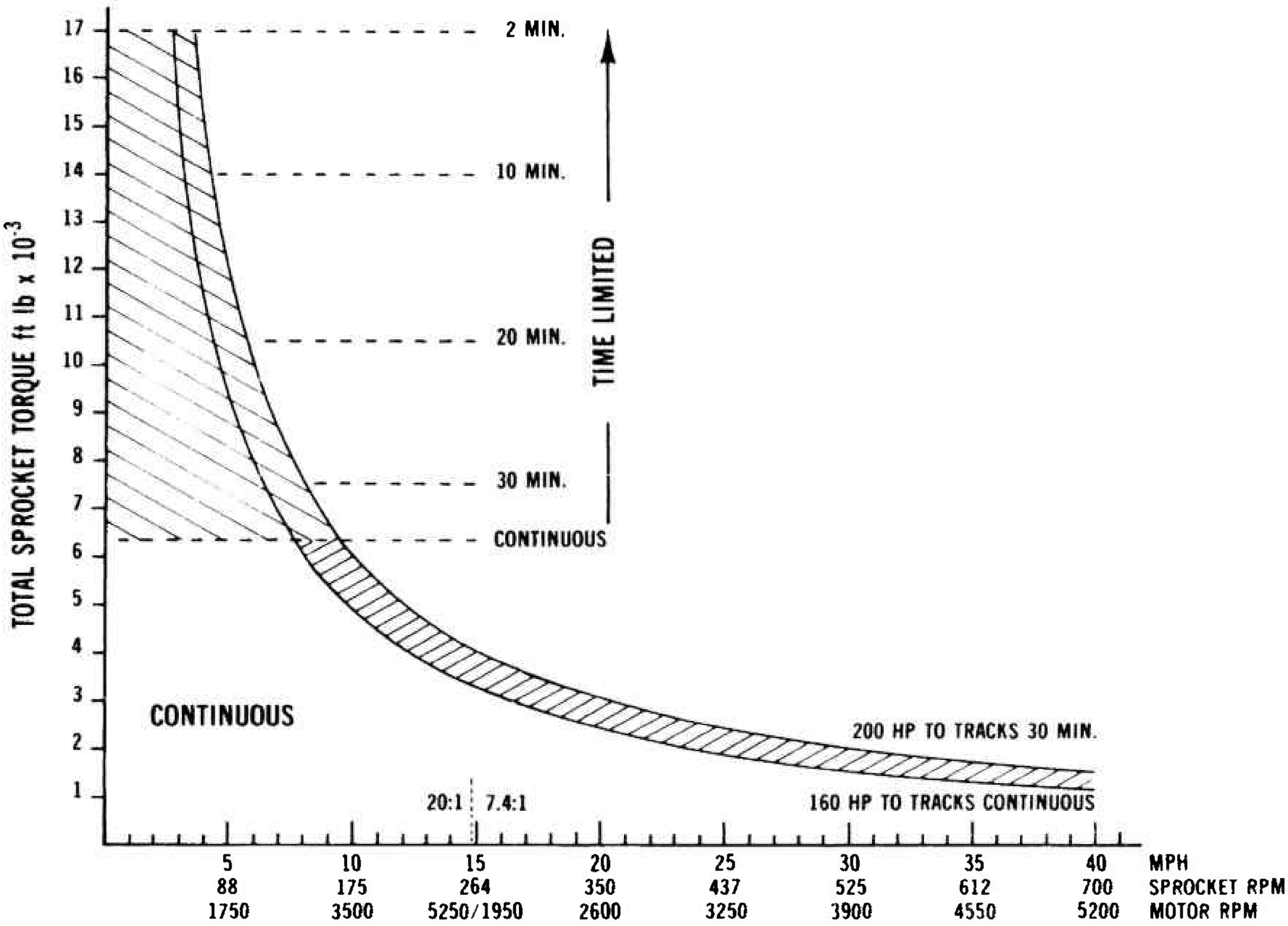


Figure 5. Calculated M113 electric-drive system performance.

Again referring to the GE computer runs, full motor speed will be reached when motor field voltage is decreased to approximately 12.5 V. In low gear maximum motor speed results in 15-mi/h vehicle speed; to further increase speed the gear must be shifted to high. Maximum motor speed will then result in 5200/7.4 = 700 r/min sprocket speed or 40 mi/h vehicle speed.

If high starting torque is not required, the vehicle can be run through the speed range in high gear, total starting torque would then be 2 x 7.4 x 433 = 6400 ft-lb, or total tractive effort of 8000 lb. Referring to Figure 5, any power curve can be followed through the speed range according to the operator's wish. Maximum performance is 200 hp to the tracks, but is theoretically time limited, as noted in Figure 5. In practice, this limitation might be disregarded since it is unlikely that a condition will be encountered where full power will be required for 30 uninterrupted minutes. Below the 160-hp curve and above 8 mi/h, vehicle operation is continuous. Low speed, straight ahead on 60 percent grade requires a total of 12,400 ft-lb sprocket torque. This requirement is well within the drive system's short term capability, but time-limited operation will apply. The requirement for high speed, straight ahead is 120 hp per side with a sprocket speed of 750 r/min. Since maximum sprocket speed for this investigation is 700 r/min, the horsepower requirement will be 112 hp per side. However, with 270 hp available for traction, an efficiency of 83 percent would be required to transmit a total of 224 hp to the tracks. With a maximum estimated efficiency of 75 percent this requirement cannot be met.

Vehicle steering is accomplished by control of the motor fields, and steering control will be continuously variable with regenerative transfer of energy from one side to the other. When, as an example, a sharp right turn is required, the field on the right motor must be increased to force the motor to slow down. At the same time, the field on the left motor is decreased and the left motor will try to increase in speed. The right motor then gets into the generating mode supplying power to the left motor and, in doing so, holding back on the right track while the left motor will speed up the left track and thus force the vehicle into a right turn.

The field current to the two motors is supplied from the Bendix d.c. generator through two high-current switching transistor power supplies, which are controlled by the micro-computer with inputs from the operator's controls.

High-speed turns require power delivery to the outer motor greater than the engine can deliver. However, with the regenerative transfer capability the inner motor operating in the generator mode will supply the difference. One of the original requirements is a high-speed, clockwise turn, requiring 293 hp to the left sprocket at 770 r/min sprocket speed and 113 hp generated by the right sprocket motor at 740 r/min sprocket speed. Since top sprocket speed is 700 r/min, the required power will be 293 x 700/770 = 266 hp and 103 hp generated. According to the GE computer run, this is within the capability of the motor.

Pivot steering is accomplished by reversing the field on one of the motors. The requirement for a pivot turn is +9000 ft-lb to one sprocket and -9000 ft-lb to the other. this is more than the 8500 ft-lb per side agreed upon but will be within the capability of the system.

Dynamic braking is accomplished by connecting the motors to a braking grid and applying excitation. The motors will then generate power which will be dissipated in the braking grid. Since the motor excitation is individually controlled, steering will function normally.

8. **Operator Controls and Functions.** The control system will consist of operator input controls, a digital processor, analog output controllers, and vehicle parameter feedbacks. A block diagram of the basic control functions is shown in Figure 6. The processor itself, operator control hardware, engine controller, and software routines in common with the hydrostatic effort will be purchased from Southwest Research, Inc. The analog controllers additional programming and hardware, assembly, and debugging will be done by MERADCOM. Functions of the operator controls are discussed below:

a. **Accelerator.** Sets desired vehicle speed. Signal will be compared to actual vehicle speed and accelerated at a rate proportional to the difference. Initiation of acceleration consists of increasing engine speed, alternator field current, and motor field currents, followed by a decrease of motor field to increase speed.

b. **Brake.** Overrides accelerator. First part of brake travel will activate proportional dynamic braking, further travel will pickup the hydraulic disc brakes via a master cylinder.

c. **Steering.** Sets a desired track speed differential, which is accomplished by inversely adjusting the motor field currents. Steering response should be slow on center and faster toward end stops. Pivot steering becomes available toward the end stops.

d. **Selector Functions—R N H D.** Reverse—allows operation in low gear only in reverse direction; will be inhibited if vehicle has forward velocity. Neutral—engine speed controlled by accelerator position; alternator field disabled; steering and braking functions normal; manually apply hydraulic brake to park. High—allows operation in high gear only; will be inhibited if vehicle has reverse velocity. Drive—allows operation in low gear under 15 mi/h; automatic shifting at 15 mi/h.

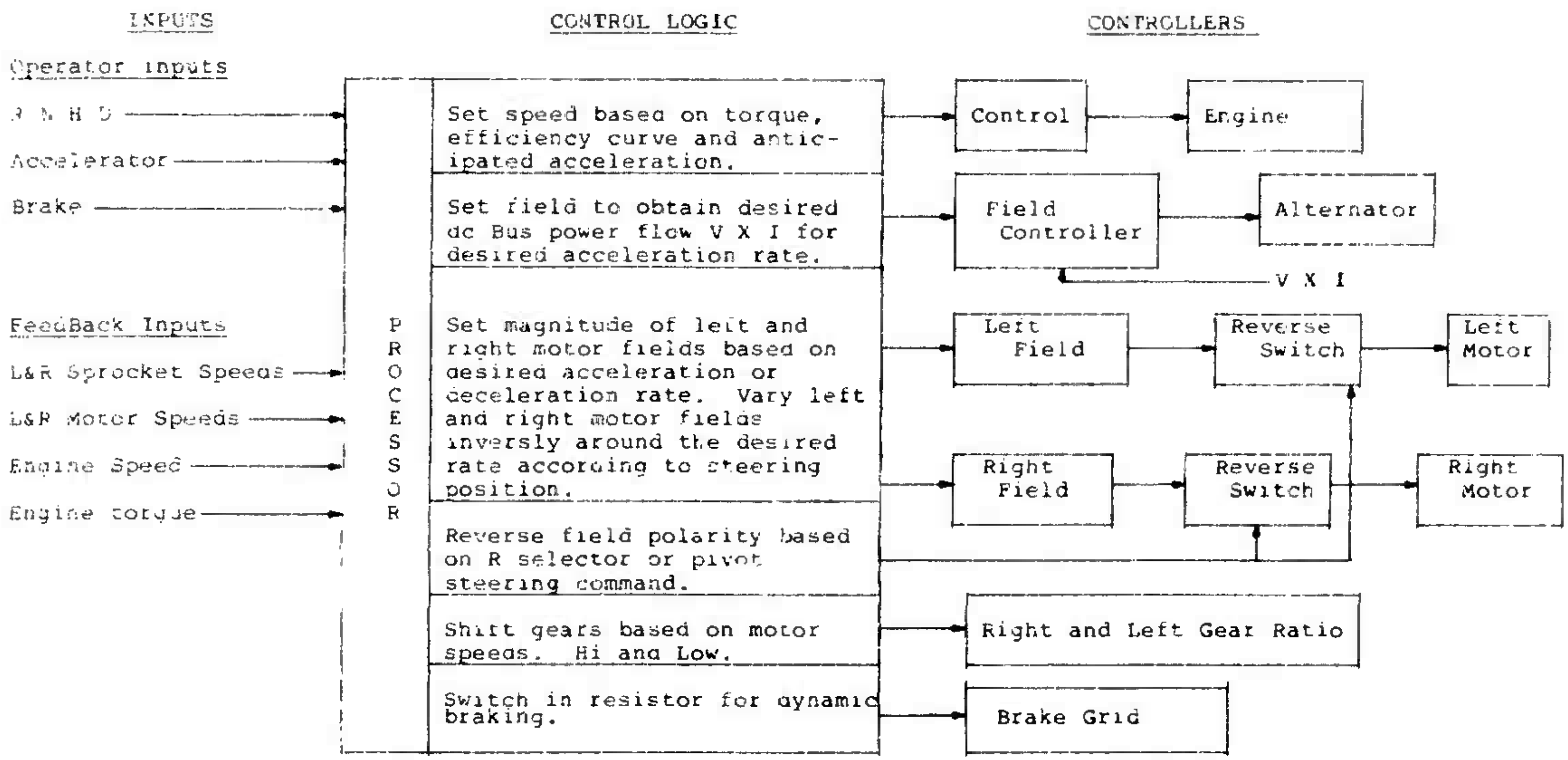


Figure 6. Control functions for M113 electric-drive system.

9. Weight Estimates. Estimated weights are in the following table:

Weight Estimates

Component	Weight (lb)	Number Required	Total Weight (lb)
Alternator	430	1	430
Belt Drive	95	1	95
Rectifier	110	1	110
Drive Motors	495	2	990
Motor Field Supply	45	1	45
Controls	90	1	90
Gears	180	2	360
Final Drive	220	2	440
Braking Grid	75	1	75
			2635
Misc. Cables, Blowers, etc. 5 percent			132
Total Proposed			2767
Lightweight option: Oil-cooled Alternator and Rectifier			2430

10. Potential Weight Savings. The specific weight of the system as proposed is 9.2 lb/hp. There are several ways in which this specific weight might be reduced:

a. Replacement of the proposed alternator with the two high-speed oil-cooled machines discussed earlier and selection of the lightweight fluid-cooled rectifier option will save 335 lb, or 1.1 lb/hp.

b. Component technology can be improved. One could develop higher speed motors with a likely saving of 75 lb and a single high-speed alternator saving, perhaps another 25 lb. Combined, these developments would yield another 1/3-lb/hp saving. One of the heaviest components where weight savings may be possible is the gearing. The proposed system weight includes 800 lb of gears. It seems worthwhile from a system point of view to integrate the motors and gears and to develop lightweight gear technology. We have not estimated the weight savings from such efforts.

c. One can develop better overall electric-drive technology by identifying opportunities for weight and volume savings during developmental testing of the demonstrator. The demonstrator, as proposed, will yield important data on the performance of the electric drive under computer control in the variety of operating conditions which the amphibian will encounter. It is likely that these data w ll advance electric-drive technology by providing improved specifications and requirements for system engineering.

APPENDIX A

BENDIX BRUSHLESS GENERATOR, TYPE 28B329-1 IDG

DESCRIPTION.

A single-bearing generator, the 28B329-1 is designed to share a bearing with a constant speed drive and to utilize the drive's oil for cooling. The generator bolts directly to the drive, and integration involves the mating of the drive spline and oil-in, oil-out ports.

A complete AC machine, the 28B329-1 is extremely lightweight. It weighs only 75 lb, yet it carries an output rating of 150 kVA, and has full overload capabilities.

Similar to other Bendix IDG generators, the 28B329-1 utilizes both conduction and oil-mist spray cooling techniques to provide optimum heat transfer characteristics.

Cooling. Cooling oil from the drive enters the generator at the mating flange interface where it goes through a short connecting channel and then into a series of grooves in the housing.

The grooves surround the generator stator core which is shrunk into the machined bore of the housing to form a channel through which the cooling oil flows.

Oil flow through the channel is turbulent and it contacts all surfaces of the channel including the stator core to provide optimum heat transfer.

The oil then leaves the stator cooling passages, and flows through a cast-in channel to the anti-drive end of the generator. Here, a small amount of oil is metered through a clearance to first lubricate the bearing and then to spray the permanent-magnet generator.

Most of the oil enters the rotor through a hollow generator shaft where it proceeds towards the drive end. Metering orifices in the shaft provide a means of distributing the cooling oil in the proper quantity and in the right places to do an effective cooling job.

The first orifice discharges a jet of oil into the rotating diode heat sink area to remove heat from the diodes and then to spray and cool the exciter armature.

The oil in the shaft next is metered through orifices at the main generator rotor where it is first distributed over the rotor windings and then sprayed over the stator end turns. A unique design feature directs the oil to flow between the rotor poles to carry away heat from these areas. The same oil is then used again to spray and cool the stator winding end turns. This cooling technique is extremely efficient and operating temperatures of the generator stabilize very rapidly.

Insulation. Insulation used throughout the 28B329-1 is DuPont's "Nomex" and our own RB-160 insulating material. The combination of these two materials provides optimum heat transfer characteristics.

RB-160, used to impregnate the wound assemblies of the generator, also has great mechanical strength to provide excellent bonding within the windings. These are important characteristics since movement within the windings due to vibrational stresses is prevented.

Tables I and II show insulation life and thermal conductivity of the installation used in the 28B329-1.

Specifications

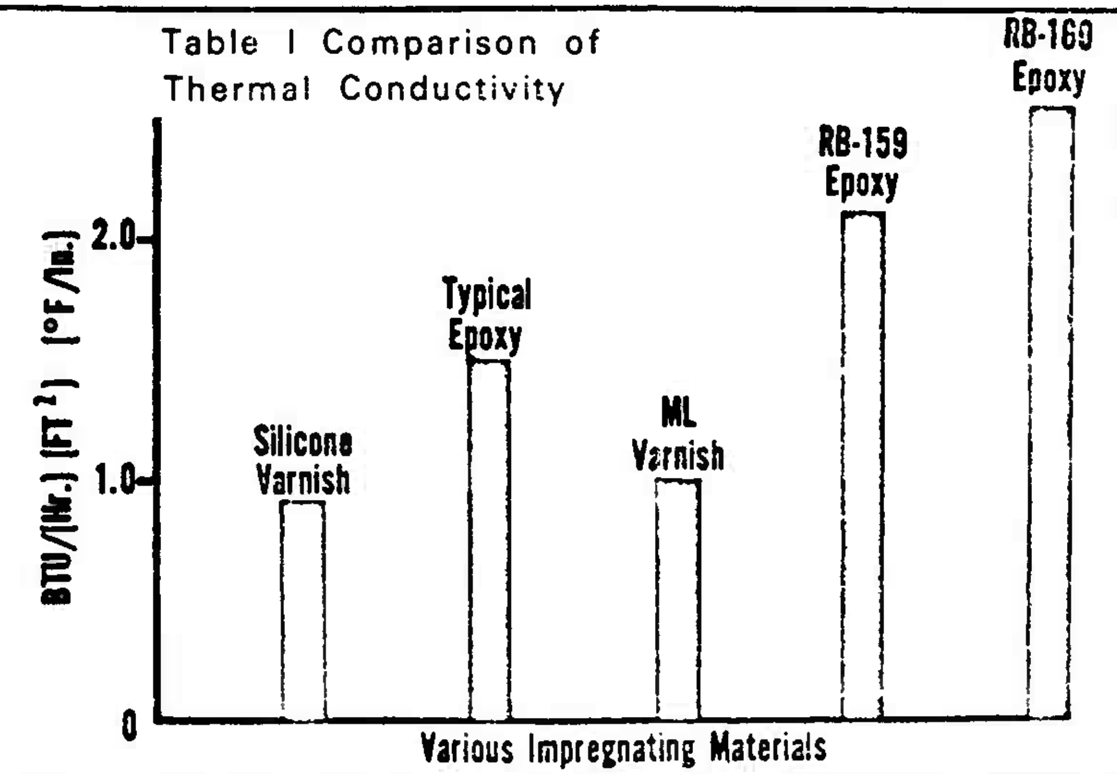
- Rating: 150 KVA, continuous output @ .75 PF, 120/208 volts, 3 phase, 4-wire, 400 Hz at 12,000 RPM
- Cooling Oil: Oil-in @ 250°F and flow at 7.5 gpm @ 230-240 psi
- Weight: 74 lbs.

PMG Output: 42 ± volts

Design Features

- Oil-cooled by conduction and oil-mist spray
- Integrates with drive to provide compact compact drive-generator package.
- Lightweight unit has weight-to-output ratio of only .5 lb./KVA.
- PMG excitation source with solid-state control unit eliminates need for external excitation and produces excellent generator output characteristics.
- Cooling techniques provide extremely effective cooling system with conservative generator operation
- Insulation system is completely compatible with, and unaffected by MIL-L-7808, MIL-L-23699 hydraulic fluids.
- Integration with drive makes up lightweight overall package.
- Brushless design provides long service life and low overhaul/maintenance costs.

Table I Comparison of Thermal Conductivity



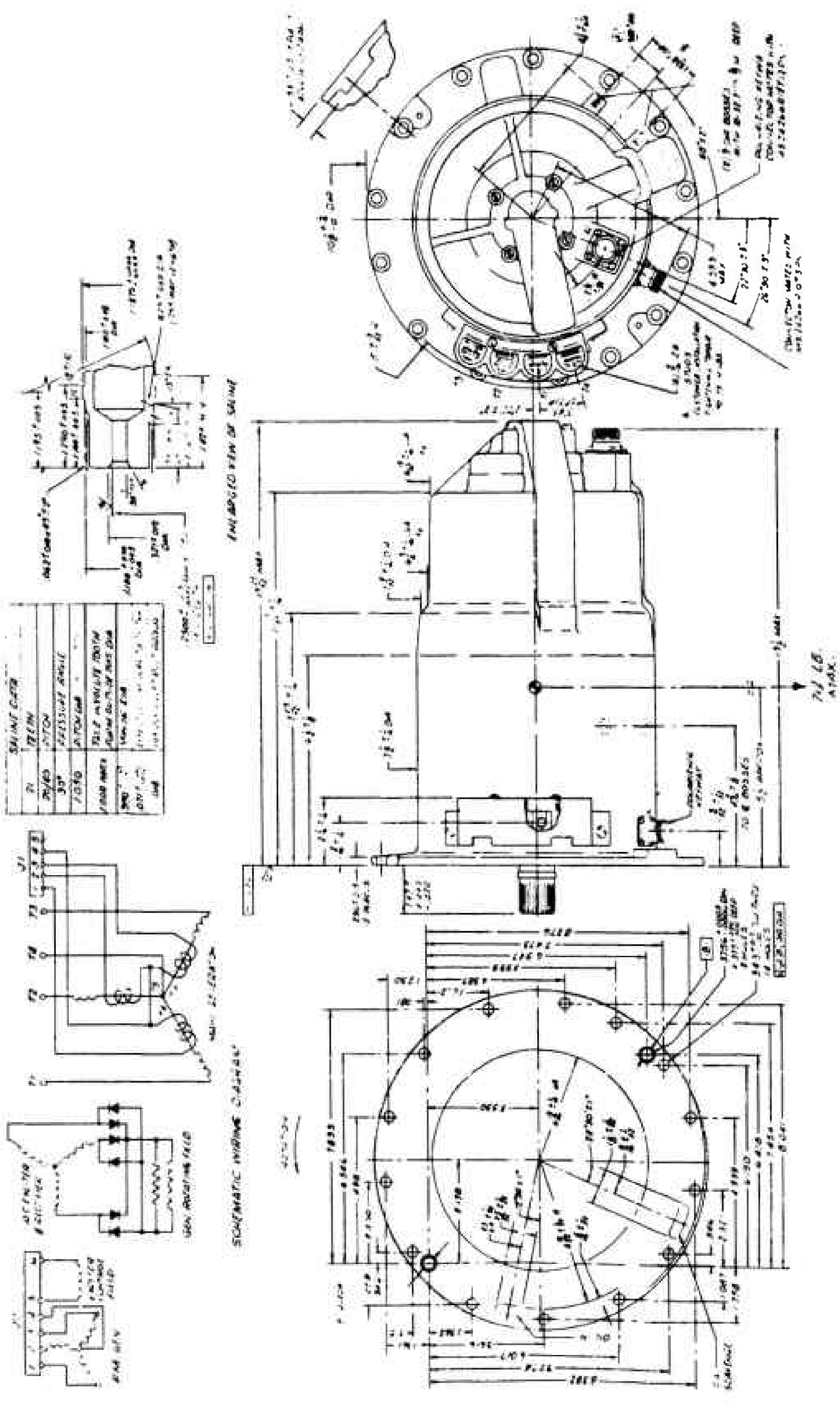
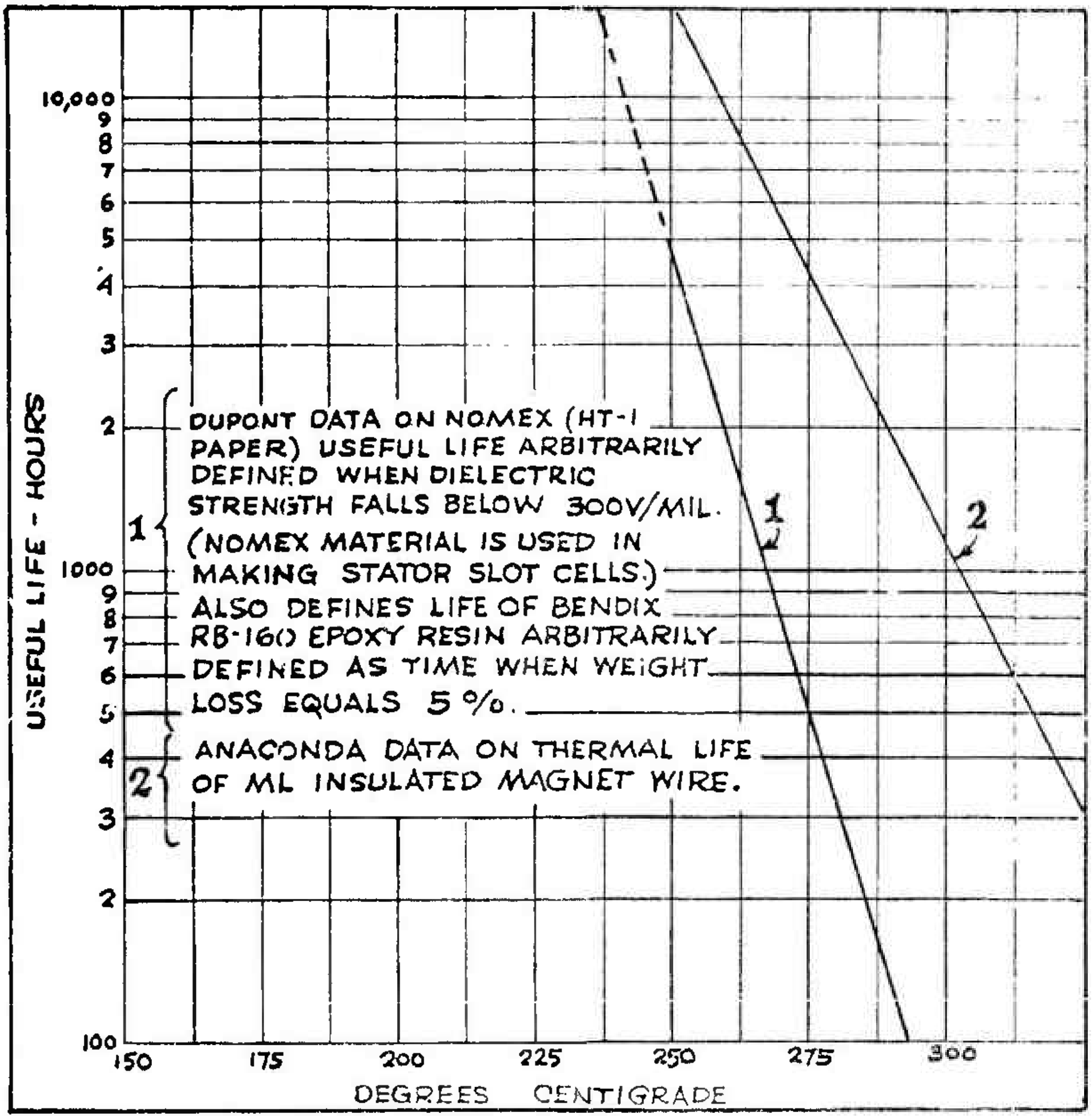
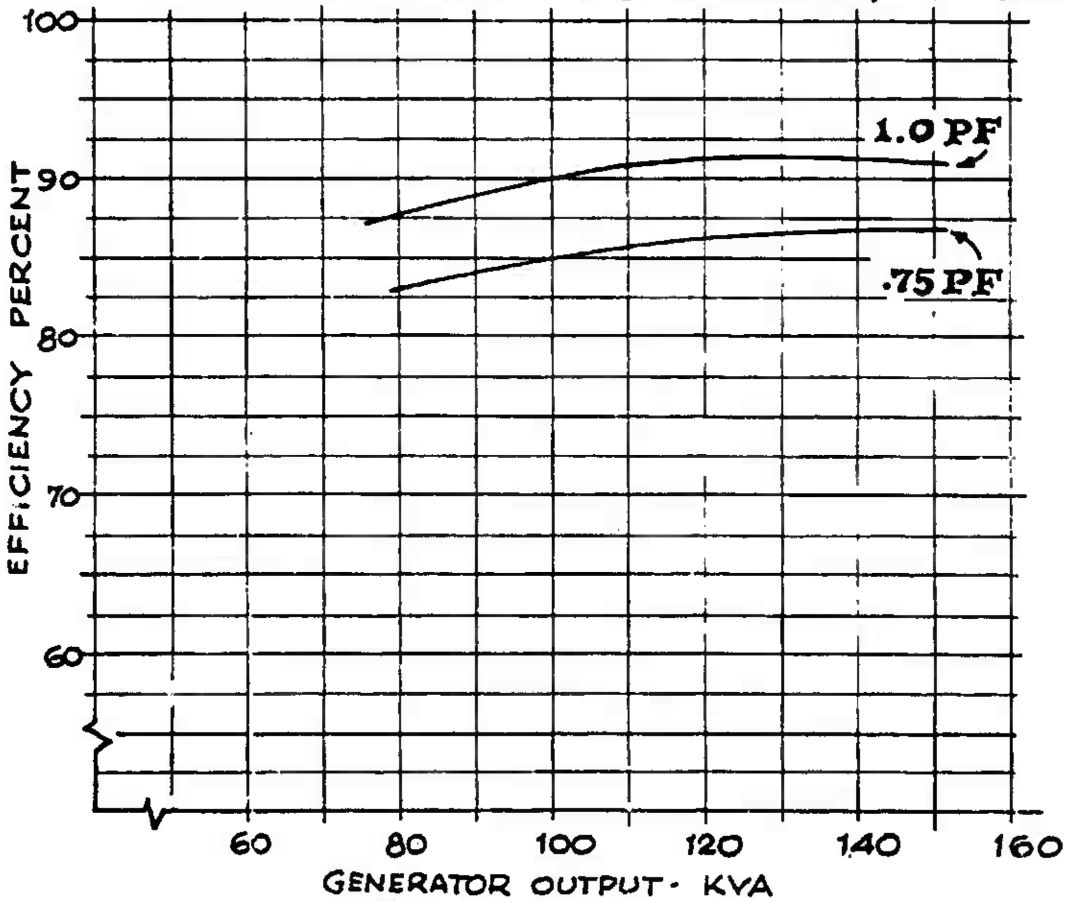


Table II Insulation Life



EFFICIENCY CURVES, 28B329-1 IDG
GENERATOR S/N 2 @ 12,000 RPM; OIL IN @250°F.



OVERLOADS

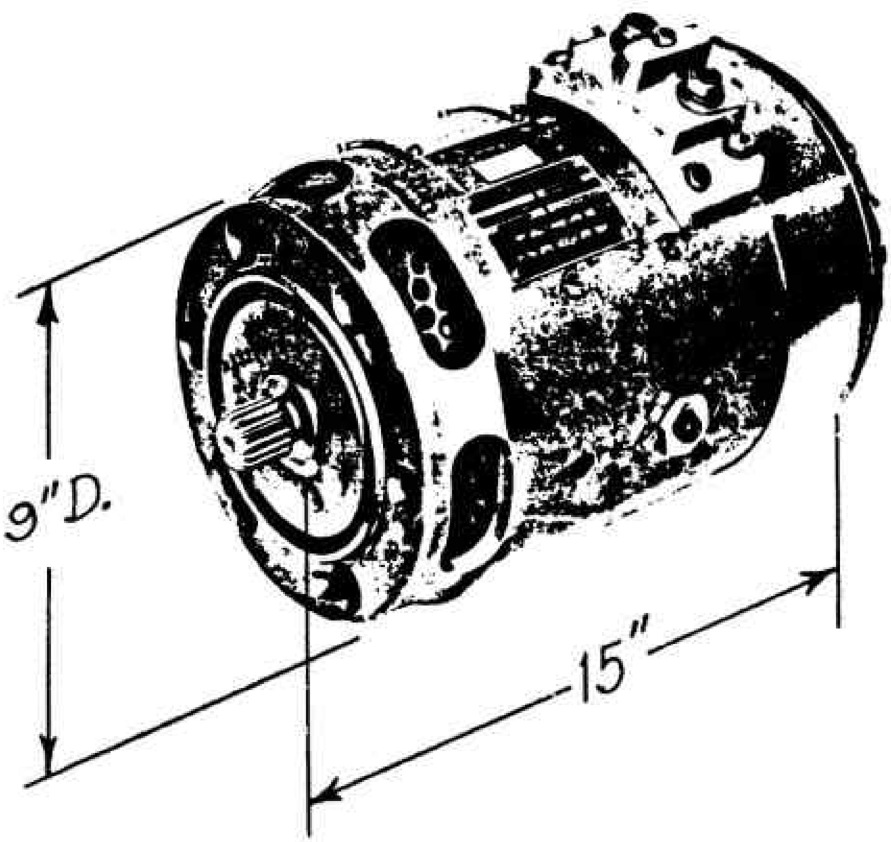
			GEN. VOLTAGES			LOAD			FIELD	OIL °C	TIME	
RPM	KVA	P.F	T1·T4 T1·T2	T2·T4 T2·T3	T3·T4 T3·T1	KW1 I1	KW2 I2	KW3 I3	E_F I_F	IN OUT	MIN	REQ'D
12000	150	.75	119.8 207	119.7 207	119.5 207	37.5 416	37.5 416	37.5 416	17.2 2.90	118 129	0	
12000	150	.75	119.8 207	119.7 207	119.5 207	37.5 416	37.5 416	37.5 416	17.2 2.90	120 129	5	
12000	150	.75	119.9 207.5	119.8 207.5	119.8 207.5	37.5 416	37.5 416	37.5 416	17.5 2.90	120 131	10	
12000	150	.75	120 208	120 207.5	119.9 208	37.5 416	37.5 416	37.5 416	17.5 2.90	120 131	20	
12000	225	.75	119.8 207	119.2 206	119.0 207	56.25 634	56.25 624	56.25 624	26.5 4.35	120 130	0	208V ± 2%
12000	225	.75	119.4 206.5	119 206	118.9 207	56.25 624	56.25 624	56.25 624	28.0 4.45	120 140	5	
12000	225	.75	119.5 207	119 206	118.9 207	56.25 624	56.25 624	56.25 624	28.0 4.45	121 140	10	
12000	300	.75	118.5 205.5	-	-	75 832	75 832	75 852	40.0 6.54	-	5 SEC	208V ± 3.5%

WAVEFORM

		NO LOAD		KVA LOAD @ .75 PF 75		150		KVA LOAD @ 1.0 PF 75		150	
RPM	FUND. HARMC	L-N	L-L	L-N	L-L	L-N	L-L	L-N	L-L	L-N	L-L
12000	1	100	100	100	100	100	100	100	100	100	100
12000	3	–	–	–	–	–	–	–	–	–	–
12000	5	1.37	1.34	.6	.6	.62	.64	1.5	1.46	2.4	2.4
12000	7	1.54	1.54	1.7	1.7	1.7	1.7	1.55	1.45	1.97	2.0
12000	9	–	–	–	–	–	–	–	–	–	–
12000	11	.52	.53	.56	.56	.41	.42	.41	.37	.46	.45
12000	13	.36	.38	–	–	<.1	<.1	<.1	<.1	.25	.28
12000	15	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
12000	17	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	.23	.22
12000	19	.17	.17	<.1	<.1	<.1	<.1	<.1	<.1	.28	.27
12000	21	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
12000	23	.27	.27	.20	.22	<.1	<.1	<.1	<.1	.23	.23
12000	25	<.1	<.1	.17	.16	<.1	<.1	.15	.14	.17	.18
12000	27	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
12000	29	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1

NOTE: ALL HARMONICS ABOVE 29TH ARE LESS THAN 0.1%

PROPOSED BENDIX TRACTION MOTOR



40 HP DC MOTOR
8000 RPM
100 VOLTS, DC
140 LB

APPENDIX B

GENERAL ELECTRIC TEST RESULTS

GENERAL ELECTRIC
COMPANY

777 FOURTEENTH STREET, N. W., WASHINGTON, D. C. 20005 . . . TELEPHONE EXecutive 3-3600

DEFENSE PROGRAMS DIVISION

EQUIPMENT AND COMPONENT FIELD OPERATION

January 13, 1969

Department of the Army
MERDC
Fort Belvoir, Virginia 22060

Attention: Mr. C. Heise

Gentlemen:

The attached information hopefully provides sufficient data for your present planning. J. Nadzam will check the engineers to determine if additional tests are planned so that you may have a complete speed torque curve family. At one time, this action was contemplated but the availability of test equipment was delayed.

Very truly yours,

C. J. White/ra

C.J. White
Manager - Ground Power Programs

CJW/ra

Encl.

GENERAL ELECTRIC

Dial Comm: 8*342-2981 Date: November 26, 1968 Copies: GF Bond, 64-3
WG Brighton, 17-2

Dept: Direct Current Motor & Generator Dept.

Address: 3001 East Lake Road, Erie, Pa. 16501

Subject: Type BY401 Motors for ERDL

RECEIVED
OFF HIGHWAY VEHICLE
EQUIPMENT PROJECT
NOV 27 1968
TEPMO
TRANSPORTATION SYSTEMS DIVISION

Mr. J. P. Nadzam
Bldg 42-3

A little over one year ago we shipped 5 motors to ERDL for powering an experimental vehicle. Questions from the customer on overload capability of the motor prompted us to suggest that they return one motor to us for testing with a dynamometer facility that was not available at the time the motors were initially shipped. This facility has permitted us to test the motors at speeds up to 8000 r/min and at outputs of 100 hp or more. We have now completed these tests with the results as shown on the attached two curve sheets.

The attached curve sheet "Duty Cycles and Short Time Ratings" is particularly interesting because it is a complete statement of the thermal capability of the motor on any type of repetitive load.

You will observe that the maximum duration for an overload condition is somewhat shorter than we had previously indicated that it would be. The following observations are appropriate.

(1) The maximum capability of the motor is 102 lb-ft for one minute. This is simultaneously a thermal and a commutation limitation. At this torque, and at 6000 r/min, 116 hp will be delivered by the motor.

(2) The rated maximum speed of the motor is 8000 r/min. Any speed greater than this value should be considered an overspeed. The maximum safe speed is 10,000 r/min.

Our tests disclosed that when operation at high currents and high speeds will be frequently repeated, two changes will improve commutation, brush life, and commutator life. These are:

(a) Change brush grade to L-206.

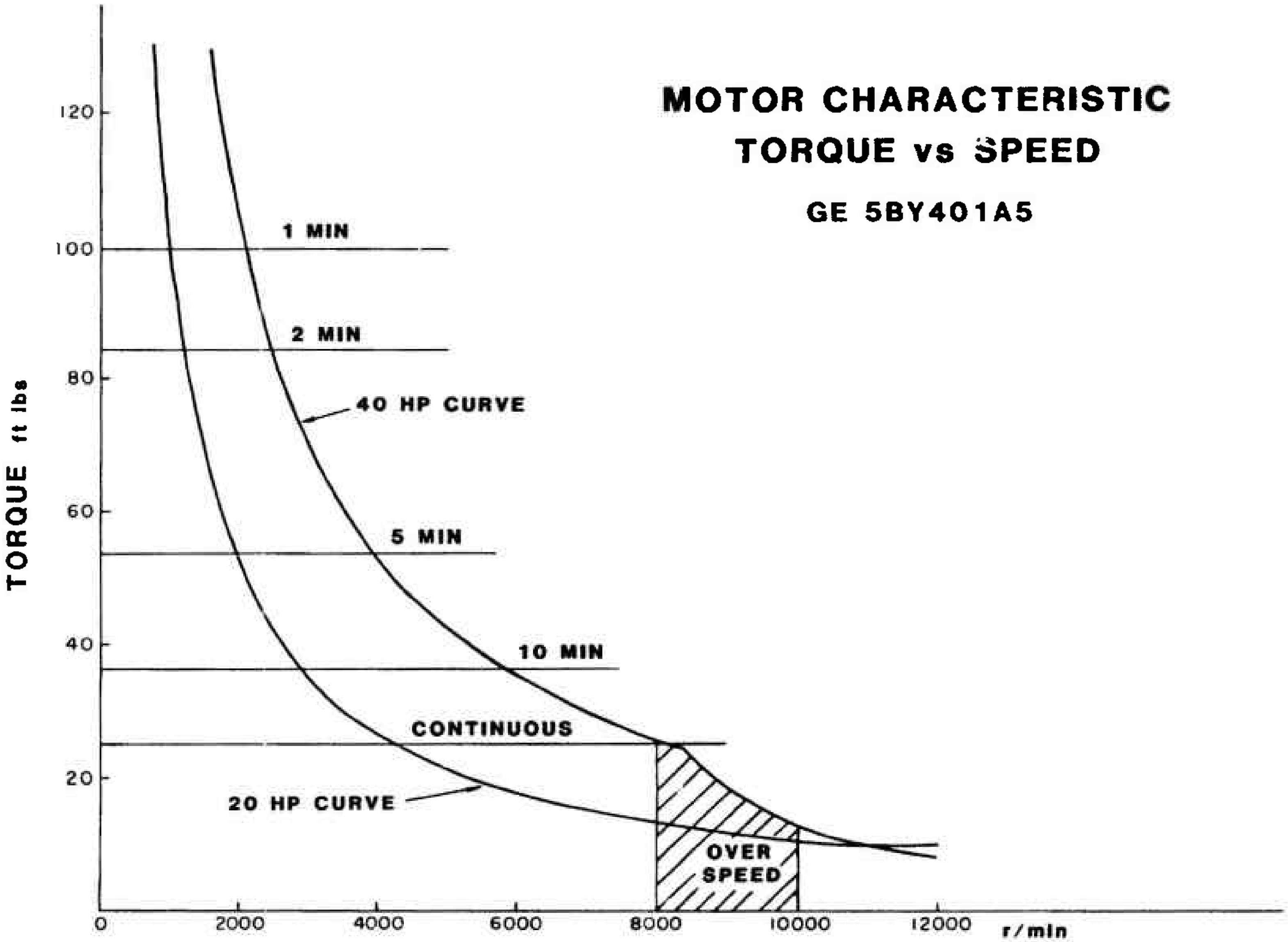
(b) Increase spring pressure 50 percent.

I am attaching a copy of Mr. Bond's test report, from which you can see the importance of these changes. We understand that the customer is interested in converting from shunt to series windings. At the time the machines are returned to us for conversion we would plan to install the new brushes and springs. He should, at the same time, return the two motors to us which have already been converted to series windings in order that we can make the brush and spring changes as well as recheck the machines thoroughly to see that they are in top condition.

/s/
C. M. Wheeler, Supervisor
Special Product Engineering
Specialty Motor Product Engineering Subsection
Bldg. 64B-3, Ext. 2981

Attachments

MOTOR CHARACTERISTIC
TORQUE vs SPEED
GE 5BY401A5



Brush Tests on Model 5BY401A5

The motor is a series wound machine, separately ventilated and is rated 40 hp, 8000 r/min, 96 V, 345 A continuous duty—100 hp, 6000 r/min, 96 V, 920 A, 20 s short time duty.

The customer, Mobility Equipment R&D Laboratories anticipated the motor's capabilities as shown in Figure 1 and requested our comments on the "time-on" values for the various load conditions.

Tests have been taken and the important results are included in this report.

Conclusions.

(1) The commutator was designed for operation at 8000 r/min and tests confirm commutator stability at this speed. No load overspeed is 10,000 r/min.

(2) Brushes should be changed to grade L206.

(3) Brush springs should be changed to give 50 percent additional pressure.

(4) For load currents exceeding rated, the operating time is limited by brush temperatures rather than winding temperatures.

Tests.

(A) Black band tests were taken to confirm compensation and to compare different brush grades. Tests were at half rated volts. Vibration required the use of double-pressure springs.

(1) Grade 537. This is one of the original brushes, preferred for good wear properties. Black band is narrow and closes at less than peak current.

(2) Grade 456. Favored brush for low contact drop, but rejected for poor wear. Has open band to peak current.

(3) Grade L206. Recommended by Carbon Products. This split brush has very wide band.

(4) Grade L206 solid. Poor band.

(B) Tests were taken to find "time-on" values at points on or below the characteristic curve. Brush temperature by thermocouple and winding temperature by volt drop were observed. The motor was run to selected speed and load current as quickly as possible.

Results (CW rotation only)

LV	LA	r/min	Comm	°C Brush Temp	Time On	Remarks
67.5	1000	4000	1-1 ½	250	1.3 min	L206 split brush
93	1000	6000	1-2	250	1.25	heavy springs
94	800	6500	2	250	2.5	
92	650	6800	2	250	4.75	high friction
58	350	6000	1	150	Cont	
66	1000	4000	1 ¼-3	230	1 min	L206 split brush
95	800	6500	2-3	200	1.2	light spring
94	650	6800	2-3	200	2.5	
88	450	7500	2-3	175	3.25	worse sparking accounts
61	350	6000	1	130	Cont	for short times
62	1000	4000	1-2	200	2.25 min	456 heavy spring
—	1000	6000	2	150	1	shut down due to
87	800	6000	3	175	1.5	brush dusting
—	1000	4000	—	—	—	456 light spring severe sparking streamers
—	1000	4000	—	—	—	SA45 light spring vicious sparking

The L206 split brush is clearly the most successful. A spring of 6 lb/in.^{2} would be a compromise between high brush friction (with double spring at 8 lb/in.^{2}) and poorer commutation with the normal spring. Brush temperatures indicate a strict time limit on overloads, and it may be concluded that an increase in brush area and commutator size is needed to achieve more reasonable short time ratings where an application of this motor demands such ratings.

APPENDIX C

GEAR DESIGN CALCULATIONS

2723:DPG:mmp
23 September 1982

MEMORANDUM

From: Code 2723 (D. Guimond)
To: MERADCOM (C. Heise)
Via: Code 2723

Subj: Final drive gearbox; preliminary design for

Ref: (a) Meeting on 10 Sep 82 btwn G. Anderson (DTNSRDC, Code 2723) and MERADCOM personnel at DTNSRDC, Carderock

Encl: (1) Design Calculations

1. In support of your work with Mark Rice, of the Marine Corps Project Office, for the design of final drive for tracked vehicles and based on the requirements discussed in reference (a), preliminary designs were worked out for two gearboxes to obtain estimates of size, volume, weight and cost.

2. The first gearbox consists of three input pinions (each being driven by an electric motor) meshing with a central output gear giving a reduction ratio of 2.8:1. Each pinion has a pitch diameter of 2.857". The gear has a pitch diameter of 8.000". The gearbox would be approximately 14.00" in diameter and 4.50" wide. The weight would be 66 lbs.

3. The second gearbox is a planetary arrangement taking as it's input the output of gearbox No. 1. It consists of an input sun gear, five planet gears and a ring gear held stationary by a clutch or brake. The output is taken from the planet gear carrier, with the overall reduction being 2.5:1. The unit can be by passed by releasing the clutch holding the ring gear and energizing a second clutch which connects the input sun gear to the ring gear, locking the planet gears, to achieve a 1:1 ratio. The unit would have overall dimensions of 13.00" diameter by 5.50" wide and weighs 58 lbs.

4. Funk Manufacturing Company has been asked to supply cost and lead time estimates for 2 of each unit.

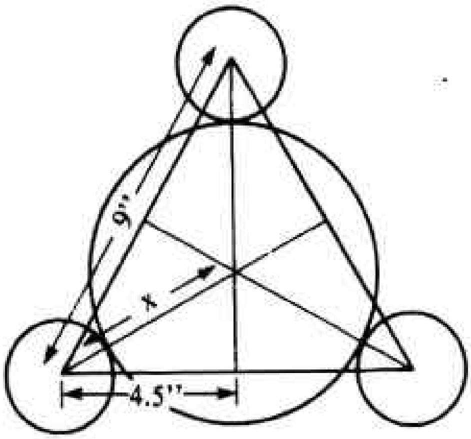
5. The gearboxes should have a life of at least 600 hours. Rough design calculations are included in enclosure (1).

David P. Guimond

David P. Guimond
Ext. 2362

Copy to:
Code 2723
Code 1120 (Mark Rice)
Code 2723S

2.8:1 Simple Mesh



$$\cos 30° = \frac{4.5}{x}$$

$$x = \frac{4.5}{\cos 30°} = 5.20$$

center distance = 5.20"

$$\frac{d_G + dp}{2} = 5.20 \qquad 2.8 = \frac{d_G}{dp} \qquad d_G = 2.8\,dp$$

$$\frac{2.8\,dp + dp}{2} = 5.20 \qquad \frac{3.8\,dp}{2} = 5.20$$

dp = 2.737" smallest
d_G = 7.664" possible

$$N_p = 40 \qquad N_G = 112 \qquad \frac{112}{40} = 2.8$$

$$P = 14 \qquad d = \frac{N}{P} \qquad dp = \frac{40}{14} = 2.857" \qquad dg = \frac{112}{14} = 8.00"$$

dp = 2.857"	dg = 8.00"	F = 1.50"
N_p = 40	N_g = 112	J = .495

Bonding Stress

$$S = \frac{4.8\,TN}{Fd^2JB} = \frac{4.8\,(120)\,(12)\,(40)}{(1.50)\,(2.851)^2\,(.495)}$$

$$\boxed{S_b = 45{,}619 \quad \text{PSI}}$$

K Factor

$$K = \frac{W}{Fd_pB}\;\frac{Mg+1}{Mg} \qquad W = \frac{2T}{d} = \frac{2(120)(12)}{2.857} = 1008 \text{ lb.}$$

$$K = \frac{1008}{1.5\,(2857)}\left(\frac{2.8+1}{2.8}\right)$$

$$\boxed{K = 319}$$

Size & Weight

$$Fd_p^2 = 1.5\,(2.857)^2 = 12.24 \times 3 = 36.73$$

$$Fd_g^2 = 1.5\,(8.00)^2 = 96$$

$$\Sigma Fd^2 = 132.73 \times .5 = 66.365$$

$$\underline{\underline{\text{Weight} = 66\text{ lb.}}}$$

$$\left[5.20 + \frac{2.857}{2}\right]2 = 13.257 \qquad \underline{\underline{14\text{'' dia.}}}$$

$$F = 1.5 \qquad 3F = 4.5 \qquad \underline{\underline{4.5\text{'' wide}}}$$

2.5:1 Planetary

Input Torque $120\,(12)(3)(2.8) = 12{,}096$ lb. in.

Speed $\frac{8000}{2.5} = 285.$ RPM

2.5 ratio $\frac{Nr}{Ns} = 1.5$ $\quad Ns = 80 \quad Nr = 120$

$$Np = \frac{Nr - Ng}{2} = \frac{120 - 80}{2} = 20 \qquad \frac{Nr + Ng}{\#\ \text{planets}} = \text{integer} \qquad \frac{120 + 80}{5} = 40$$

$$p = 14 \qquad d = \frac{N}{p} \qquad ds = 5.714'' \qquad dp = 1.429'' \qquad dr = 8.571 \qquad F = 1.375$$

ds = 5.714"	Ng = 80	5 planets
dp = 1.429"	Np = 20	p = 14
dr = 8.57"	Nr = 120	F = 1.375"

25° Spur Gears $\quad Js = .505 \quad Jp = .405$

$$V = .2518\,\frac{ndr}{Mg} = \frac{.2618\,(2857)(8.571)}{2.5} \qquad V = 2564.31 \text{ Ft./Min.}$$

$$W = \frac{33000\ Hp}{V}\left(\frac{dr}{dr + ds}\right) \qquad Hp = \frac{Tn}{63000} = \frac{12096\,(2857)}{63000} = 550$$

$$W = \frac{33000\,(550)}{2564.31}\left(\frac{8.571}{8.571 + 5.714}\right) \qquad W = 4246.76 \text{ lb.}$$

$$K_{\substack{sun\\pinion}} = \frac{W}{BF}\left(\frac{ds + dp}{dsdp}\right) = \frac{4246.76}{5\,(1.375)}\left[\frac{5.714 + 1.429}{(5.714)(1.429)}\right] \qquad \boxed{K_{\substack{sun\\pinion}} = 540}$$

$$K_{ring} = \frac{W}{BF}\left(\frac{dr - dp}{drdp}\right) = \frac{4246.76}{5(1.375)}\left[\frac{8.571 - 1.429}{(8.571)(1.429)}\right] \qquad \boxed{K_{ring} = 360}$$

Bending Stress

$$S = \frac{4.8\ TN}{Fd^2\ JB} \qquad S_{sun} = \frac{4.8\ (12096)\ (80)}{(1.375)(5.714)^2(.505)(5)} \qquad \underline{\underline{S_{sun} = 40,976\ PSI}}$$

$$T_{planet} = T_{sun}\frac{dp}{ds} = 12096\left(\frac{1.429}{5.714}\right) = 3025\ \text{lb.-in.}$$

$$S_{planet} = \frac{4.8\ (3025)\ (20)}{1.375\ (1.429)^2(.405)5} \qquad \underline{\underline{S_{planet} = 51,075\ PSI}}$$

Weight & Size

$$\text{Weight} \simeq 9500\ \frac{Q}{K} \qquad Q = \frac{P}{N_S}\left[\frac{(Mg+1)^3}{Mg}\right]$$

$$Q = \frac{550}{2857}\left[\frac{(2.5+1)^3}{2.5}\right] = 3.30 \quad \cdot \quad 9500\ \frac{(3.30)}{540} = 57.9$$

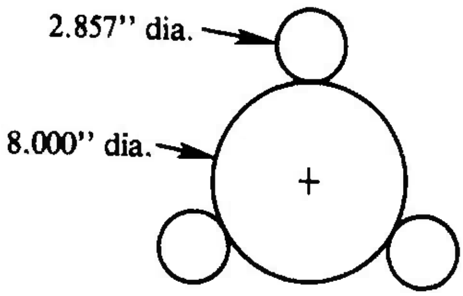
$$\underline{\underline{\text{Weight} \simeq 58\ \text{lb.}}}$$

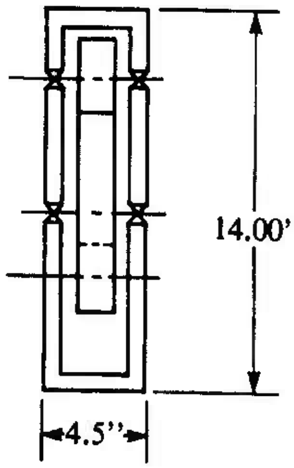
$d = 1.5\ dr \qquad d = 1.5\ (8.57) = 12.855$

$L = 3F \qquad L = 3\ (1.375) = 4.125$ + room for clutches

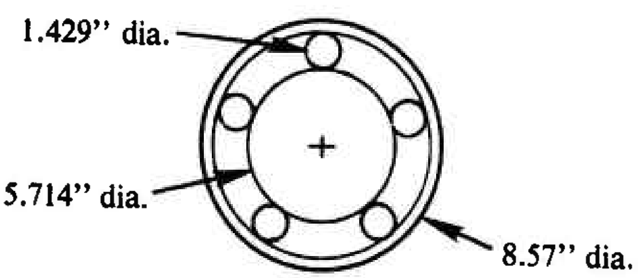
<u>13" dia. × 5.5" wide</u>

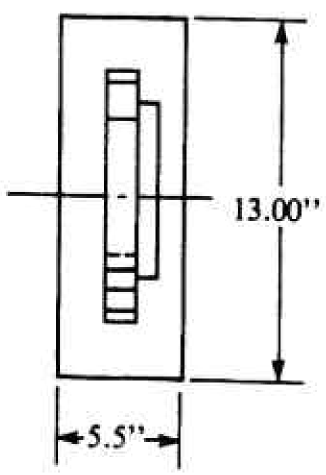
2.8:1 Ratio





2.5:1 Ratio





APPENDIX D

MOTOR PERFORMANCE

USAMERADCOM cc: Charles Faulkerson 13-2

Oct 27, 1982

Mr. Mike Mando

Enclosed find computer runs for our BT2378 motor rated:

90 hp, 5200 r/min, 120 V, 611 Amps, BV (750 CFM)

Short time ratings are shown on an attachcd sheet.

Runs were made with 48 V, 36 V, 24 V, 20 V, 16 V, 14 V, 13 V, and 12 V excitation.

Also included are runs for our BT2346 motor with 48 V and 36 V excitation.

/ s /
E. D. Elwonger
General Electric Company

USAMERADCOM

BT2378–3311

FLD = 65 T .1285″

Thermal Ratings

Time (min)	I_{ARM}	I_{FLD}
1	2574	250
2	1920	187
5	1480	119
10	1227	144
25	1040	101
30	763	50
Cont	611	40

BT2378-3311 .115 M785 USMERADCOM ELWONGER
WED, OCT 27, 1982, 9:26 AM

ELECTRIC VEHICLE PERFORMANCE-REV 7/14/81

CIRCUIT PARAMETERS

MAX STALL BAT AMPS (SCR)= 400.0 | ARM. IND. L = .11995E+00
PEAK MTR STALL AMPS(SCR)= 8918.1 | UNSAT SER L = .00000E+00
MAX STALL MTR AMPS (SCR)= 1000.0 | SAT. SER. L = .00000E+00
RB= .0000 NL BV = 120.0 | TOT. MTR. L = .95336E-01
RL= .0070 DI/DT = 1258.7 | UNSAT SH. L = .21540E+02
RA= .0057 SCRTYP= 8.0 | SAT. SH. L = .37341E+02

FIELD DATA(SPD# 2)

RSH=.4360E+00 RSHD=.0000E+00 SEV=.4800E+02 SHUNT TURNS = 65.00
RSE=.0000E+00 RS =.0000E+00 RD =.0000E+00 SERIES TURNS= .00

FOR IA) 468.750
BRUSH DROP=1.40+ .00064*IA

FOR IA (= 468.750)
BRUSH DROP= .00363*IA

MOTOR CHARACTERISTIC DATA

IB	IA	VM	TORQ	RPM	HP	LOSSES	EFF
8918.	8918.	57.6	3755.7	0.	.00	590931.	.0
4459.	4459.	88.8	1860.4	958.	339.31	148153.	63.1
3656.	3656.	94.4	1552.3	1139.	336.65	99417.	71.6
2998.	2998.	99.0	1279.8	1280.	312.05	69440.	77.0
2459.	2459.	102.8	1061.0	1380.	278.90	50016.	80.6
2016.	2016.	105.9	879.9	1456.	244.03	36773.	83.2
1653.	1653.	108.4	722.0	1529.	210.28	27720.	85.0
1356.	1356.	110.5	590.2	1593.	179.12	21511.	86.1
1112.	1112.	112.2	482.4	1646.	151.24	17235.	86.7
911.	911.	113.6	394.1	1689.	126.81	14278.	86.9
747.	747.	114.8	321.9	1725.	105.72	12223.	86.6
613.	613.	115.7	262.6	1753.	87.72	10785.	85.9
503.	503.	116.5	214.1	1777.	72.48	9773.	84.7
412.	412.	117.1	174.3	1799.	59.75	8990.	83.2
338.	338.	117.6	141.7	1819.	49.10	8420.	81.3
277.	277.	118.1	115.0	1835.	40.19	8028.	78.9
227.	227.	118.4	93.1	1848.	32.76	7756.	75.9
186.	186.	118.7	75.1	1859.	26.59	7568.	72.4
153.	153.	118.9	60.4	1867.	21.48	7436.	68.3
125.	125.	119.1	48.3	1874.	17.25	7343.	63.7
103.	103.	119.3	38.4	1880.	13.76	7278.	58.5
84.	84.	119.4	30.3	1885.	10.88	7231.	52.9
69.	69.	119.5	23.6	1889.	8.51	7197.	46.9
57.	57.	119.6	18.2	1892.	6.55	7172.	40.5
46.	46.	119.7	13.7	1895.	4.95	7154.	34.0
38.	38.	119.7	10.0	1897.	3.63	7141.	27.5
31.	31.	119.8	7.0	1899.	2.54	7131.	21.0
26.	26.	119.8	4.6	1901.	1.65	7123.	14.7
21.	21.	119.9	2.5	1902.	.92	7117.	8.8
17.	17.	119.9	.9	1903.	.32	7113.	3.2
	1000	113	433	1665	137		

FIELD DATA(SPD# 3)

RSH=.4360E+00 RSHD=.0000E+00 SEV=.3600E+02 SHUNT TURNS = 65.00
RSE=.0000E+00 RS =.0000E+00 RD =.0000E+00 SERIES TURNS= .00

FOR IA) 468.750 FOR IA (= 468.750:
BRUSH DROP=1.40+ .00064*IA BRUSH DROP= .00363*IA
INCREASED BRUSH DROP DUE TO FIELD WEAKENING = BD*2.50

MOTOR CHARACTERISTIC DATA

IB	IA	VM	TORQ	RPM	HP	LOSSES	EFF
8918.	8918.	57.6	2889.2	0.	.00	588643.	.0
4459.	4459.	88.8	1395.8	1276.	339.28	145863.	63.4
3656.	3656.	94.4	1163.0	1520.	336.60	97140.	72.1
2998.	2998.	99.0	976.5	1677.	311.99	67170.	77.6
2459.	2459.	102.8	812.1	1803.	278.83	47751.	81.3
2016.	2016.	105.9	675.3	1897.	243.96	34513.	84.1
1653.	1653.	108.4	561.6	1965.	210.20	25462.	86.0
1356.	1356.	110.5	464.9	2022.	179.05	19254.	87.4
1112.	1112.	112.2	382.4	2075.	151.17	14980.	88.3
911.	911.	113.6	312.5	2129.	126.74	12024.	88.7
747.	747.	114.8	255.2	2174.	105.64	9969.	88.8
613.	613.	115.7	208.2	2210.	87.64	8533.	88.5
503.	503.	116.5	169.7	2239.	72.40	7521.	87.8
412.	412.	117.1	138.2	2267.	59.67	6739.	86.9
338.	338.	117.6	112.3	2291.	49.02	6170.	85.6
277.	277.	118.1	91.1	2311.	40.11	5778.	83.8
227.	227.	118.4	73.7	2327.	32.68	5507.	81.6
186.	186.	118.7	59.5	2341.	26.51	5319.	78.8
153.	153.	118.9	47.8	2352.	21.40	5188.	75.5
125.	125.	119.1	38.2	2361.	17.17	5095.	71.5
103.	103.	119.3	30.3	2368.	13.67	5030.	67.0
84.	84.	119.4	23.9	2374.	10.79	4983.	61.8
69.	69.	119.5	18.6	2379.	8.42	4949.	55.9
57.	57.	119.6	14.2	2383.	6.47	4925.	49.5
46.	46.	119.7	10.7	2386.	4.86	4907.	42.5
38.	38.	119.7	7.8	2389.	3.54	4893.	35.0
31.	31.	119.8	5.4	2391.	2.45	4883.	27.3
26.	26.	119.8	3.4	2393.	1.56	4876.	19.3
21.	21.	119.9	1.8	2395.	.83	4870.	11.3
17.	17.	119.9	.5	2396.	.23	4866.	3.4

BT2378-3311 .115 M785 USMERADCOM ELWONGER
TUE, OCT 26, 1982, 5:22 PM

ELECTRIC VEHICLE PERFORMANCE-REV 7/14/81

CIRCUIT PARAMETERS

MAX STALL BAT AMPS (SCR)= 400.0		ARM. IND. L =	.11995E+00
PEAK MTR STALL AMPS(SCR)= 8918.1		UNSAT SER L =	.00000E+00
MAX STALL MTR AMPS (SCR)= 1000.0		SAT. SER. L =	.00000E+00
RB= .0000	NL BV = 120.0	TOT. MTR. L =	.95336E-01
RL= .0070	DI/DT = 1258.7	UNSAT SH. L =	.21540E+02
RA= .0057	SCRTYP= 8.0	SAT. SH. L =	.30180E+02

FIELD DATA(SPD# 2)

RSH=.4360E+00	RSHD=.0000E+00	SEV=.2400E+02	SHUNT TURNS = 65.00
RSE=.0000E+00	RS =.0000E+00	RD =.0000E+00	SERIES TURNS= .00

FOR IA > 468.750
BRUSH DROP=1.40+ .00064*IA

FOR IA <= 468.750:
BRUSH DROP= .00363*IA

MOTOR CHARACTERISTIC DATA

IB	IA	VM	TORQ	RPM	HP	LOSSES	EFF
8918.	8918.	57.6	2022.6	0.	.00	587008.	.0
4459.	4459.	88.8	920.9	1935.	339.45	144082.	63.7
3656.	3656.	94.4	763.4	2316.	336.73	95389.	72.5
2998.	2998.	99.0	641.0	2556.	312.10	65437.	78.1
2459.	2459.	102.8	542.8	2698.	278.94	46024.	81.9
2016.	2016.	105.9	459.5	2788.	244.05	32795.	84.7
1653.	1653.	108.4	387.2	2851.	210.28	23754.	86.8
1356.	1356.	110.5	327.4	2872.	179.11	17558.	88.4
1112.	1112.	112.2	272.2	2916.	151.22	13289.	89.5
911.	911.	113.6	225.5	2952.	126.78	10338.	90.1
747.	747.	114.8	186.1	2982.	105.69	8286.	90.5
613.	613.	115.7	153.0	3009.	87.68	6852.	90.5
503.	503.	116.5	125.3	3034.	72.44	5842.	90.2
412.	412.	117.1	102.2	3066.	59.70	5060.	89.8
338.	338.	117.6	83.1	3098.	49.05	4491.	89.1
277.	277.	118.1	67.5	3123.	40.14	4099.	88.0
227.	227.	118.4	54.6	3145.	32.72	3829.	86.4
186.	186.	118.7	44.1	3162.	26.55	3641.	84.5
153.	153.	118.9	35.4	3177.	21.43	3509.	82.0
125.	125.	119.1	28.3	3186.	17.20	3417.	79.0
103.	103.	119.3	22.5	3198.	13.71	3351.	75.3
84.	84.	119.4	17.7	3206.	10.83	3305.	71.0
69.	69.	119.5	13.8	3212.	8.46	3271.	65.9
57.	57.	119.6	10.6	3217.	6.50	3247.	59.9
46.	46.	119.7	8.0	3222.	4.90	3229.	53.1
38.	38.	119.7	5.8	3225.	3.58	3215.	45.3
31.	31.	119.8	4.0	3228.	2.49	3205.	36.7
26.	26.	119.8	2.6	3231.	1.60	3198.	27.2
21.	21.	119.9	1.4	3233.	.87	3192.	16.8
17.	17.	119.9	.4	3234.	.27	3188.	5.8

FIELD DATA(SPD# 4)

RSH=.4360E+00 RSHD=.0000E+00 SEV=.2000E+02 SHUNT TURNS = 65.00
RSE=.0000E+00 RS =.0000E+00 RD =.0000E+00 SERIES TURNS= .00

FOR IA > 468.750
BRUSH DROP=1.40+ .00064*IA

FOR IA <= 468.750:
BRUSH DROP= .00363*IA

MOTOR CHARACTERISTIC DATA

IB	IA	VM	TORQ	RPM	HP	LOSSES	EFF
8918.	8918.	57.6	1733.8	0.	.00	586608.	.0
4459.	4459.	88.8	756.1	2357.	339.52	143629.	63.8
3656.	3656.	94.4	624.6	2831.	336.77	94955.	72.6
2998.	2998.	99.0	524.9	3122.	312.15	65000.	78.2
2459.	2459.	102.8	445.3	3289.	279.01	45562.	82.0
2016.	2016.	105.9	380.9	3365.	244.16	32311.	84.9
1653.	1653.	108.4	323.4	3415.	210.41	23256.	87.1
1356.	1356.	110.5	275.0	3422.	179.24	17058.	88.7
1112.	1112.	112.2	234.3	3390.	151.32	12809.	89.8
911.	911.	113.6	194.8	3419.	126.88	9862.	90.6
747.	747.	114.8	161.3	3444.	105.78	7814.	91.0
613.	613.	115.7	133.0	3465.	87.77	6382.	91.1
503.	503.	116.5	109.3	3483.	72.52	5375.	91.0
412.	412.	117.1	89.6	3504.	59.79	4596.	90.7
338.	338.	117.6	73.2	3526.	49.13	4029.	90.1
277.	277.	118.1	59.5	3546.	40.22	3638.	89.2
227.	227.	118.4	48.3	3565.	32.79	3368.	87.9
186.	186.	118.7	39.0	3582.	26.62	3180.	86.2
153.	153.	118.9	31.4	3598.	21.51	3049.	84.0
125.	125.	119.1	25.1	3611.	17.28	2957.	81.3
103.	103.	119.3	20.0	3621.	13.79	2891.	78.1
84.	84.	119.4	15.8	3630.	10.90	2844.	74.1
69.	69.	119.5	12.3	3637.	8.53	2811.	69.4
57.	57.	119.6	9.5	3643.	6.58	2786.	63.8
46.	46.	119.7	7.2	3648.	4.97	2768.	57.3
38.	38.	119.7	5.2	3651.	3.65	2755.	49.7
31.	31.	119.8	3.7	3655.	2.57	2745.	41.1
26.	26.	119.8	2.4	3657.	1.67	2737.	31.3
21.	21.	119.9	1.4	3659.	.94	2732.	20.5
17.	17.	119.9	.5	3661.	.34	2727.	8.5

FIELD DATA(SPD# 5)

RSH=.4360E+00 RSHD=.0000E+00 BEV=.1600E+02 SHUNT TURNS = 65.00
RSE=.0000E+00 RS =.0000E+00 RD =.0000E+00 SERIES TURNS= .00

FOR IA) 468.750
BRUSH DROP=1.40+ .00064*IA

FOR IA (= 468.750:
BRUSH DROP= .00363*IA

MOTOR CHARACTERISTIC DATA

IB	IA	VM	TORQ	RPM	HP	LOSSES	EFF
8918.	8918.	57.6	1445.0	0.	.00	586281.	.0
4459.	4459.	88.8	580.7	3068.	339.41	143381.	63.8
3656.	3656.	94.4	477.5	3701.	336.58	94768.	72.6
2998.	2998.	99.0	401.8	4075.	311.92	64842.	78.2
2459.	2459.	102.8	343.3	4263.	278.79	45400.	82.1
2016.	2016.	105.9	295.7	4332.	243.97	32126.	85.0
1653.	1653.	108.4	255.4	4322.	210.27	23029.	87.2
1356.	1356.	110.5	219.0	4295.	179.16	16783.	88.8
1112.	1112.	112.2	188.6	4214.	151.34	12468.	90.1
911.	911.	113.6	162.5	4100.	126.94	9488.	90.9
747.	747.	114.8	135.4	4105.	105.86	7424.	91.4
613.	613.	115.7	112.1	4115.	87.86	5984.	91.6
503.	503.	116.5	92.5	4123.	72.62	4972.	91.6
412.	412.	117.1	76.0	4137.	59.89	4188.	91.4
338.	338.	117.6	62.3	4152.	49.24	3618.	91.0
277.	277.	118.1	50.8	4165.	40.33	3226.	90.3
227.	227.	118.4	41.4	4176.	32.90	2954.	89.3
186.	186.	118.7	33.5	4185.	26.73	2766.	87.8
153.	153.	118.9	27.1	4193.	21.62	2634.	86.0
125.	125.	119.1	21.7	4200.	17.39	2541.	83.6
103.	103.	119.3	17.3	4207.	13.90	2475.	80.7
84.	84.	119.4	13.7	4212.	11.02	2428.	77.2
69.	69.	119.5	10.8	4216.	8.65	2394.	72.9
57.	57.	119.6	8.3	4221.	6.69	2370.	67.8

**SCREEN CONTENTS @:WED, OCT 27, 1982, 9:28 AM

FIELD DATA(SPD# 3)

RSH=.4360E+00 RSHD=.0000E+00 SEV=.1400E+02 SHUNT TURNS = 65.00
RSE=.0000E+00 RS =.0000E+00 RD =.0000E+00 SERIES TURNS= .00

FOR IA > 468.750 FOR IA <= 468.750:
BRUSH DROP=1.40+ .00064*IA BRUSH DROP= .00363*IA
INCREASED BRUSH DROP DUE TO FIELD WEAKENING = BD*2.50

MOTOR CHARACTERISTIC DATA

IB	IA	VM	TORQ	RPM	HP	LOSSES	EFF
8918.	8918.	57.6	1300.6	0.	.00	586145.	.0
4459.	4459.	88.8	485.8	3666.	339.23	143375.	63.8
3656.	3656.	94.4	397.1	4446.	336.29	94846.	72.6
2998.	2998.	99.0	335.3	4879.	311.56	64968.	78.2
2459.	2459.	102.8	288.7	5063.	278.43	45532.	82.0
2016.	2016.	105.9	250.8	5100.	243.63	32235.	84.9
1653.	1653.	108.4	218.7	5040.	209.98	23107.	87.1
1356.	1356.	110.5	189.4	4960.	178.92	16827.	88.8
1112.	1112.	112.2	163.9	4840.	151.13	12485.	90.0
911.	911.	113.6	142.0	4687.	126.79	9461.	90.9
747.	747.	114.8	119.4	4650.	105.74	7378.	91.4
613.	613.	115.7	99.2	4644.	87.75	5924.	91.7
503.	503.	116.5	82.1	4641.	72.53	4899.	91.7
412.	412.	117.1	67.6	4646.	59.82	4105.	91.6
338.	338.	117.6	55.5	4655.	49.17	3532.	91.2
277.	277.	118.1	45.3	4663.	40.26	3137.	90.5
227.	227.	118.4	36.9	4669.	32.84	2864.	89.5
186.	186.	118.7	30.0	4674.	26.67	2673.	88.2
153.	153.	118.9	24.2	4679.	21.56	2540.	86.4
125.	125.	119.1	19.4	4686.	17.33	2447.	84.1
103.	103.	119.3	15.5	4693.	13.84	2381.	81.3
84.	84.	119.4	12.2	4699.	10.96	2333.	77.8
69.	69.	119.5	9.6	4704.	8.59	2299.	73.6
57.	57.	119.6	7.4	4708.	6.64	2274.	68.5
46.	46.	119.7	5.6	4711.	5.03	2256.	62.5
38.	38.	119.7	4.1	4715.	3.71	2243.	55.2
31.	31.	119.8	2.9	4718.	2.63	2233.	46.7
26.	26.	119.8	1.9	4721.	1.73	2225.	36.8
21.	21.	119.9	1.1	4723.	1.00	2220.	25.2
17.	17.	119.9	.4	4725.	.40	2215.	11.9

FIELD DATA(SPD# 4)

RSH=.4360E+00 RSHD=.0000E+00 SEV=.1300E+02 SHUNT TURNS = 65.00
RSE=.0000E+00 RS =.0000E+00 RD =.0000E+00 SERIES TURNS= .00

FOR IA) 468.750
BRUSH DROP=1.40+ .00064*IA

FOR IA (= 468.750:
BRUSH DROP= .00363*IA

MOTOR CHARACTERISTIC DATA

IB	IA	VM	TORQ	RPM	HP	LOSSES	EFF
8918.	8918.	57.6	1228.3	0.	.00	586084.	.0
4459.	4459.	88.8	432.5	4116.	339.07	143432.	63.8
3656.	3656.	94.4	351.7	5016.	336.02	94986.	72.5
2998.	2998.	99.0	299.1	5463.	311.24	65145.	78.1
2459.	2459.	102.8	259.5	5626.	278.10	45715.	81.9
2016.	2016.	105.9	226.8	5633.	243.32	32406.	84.9
1653.	1653.	108.4	199.3	5525.	209.72	23242.	87.1
1356.	1356.	110.5	173.9	5396.	178.70	16931.	88.7
1112.	1112.	112.2	151.2	5243.	150.95	12555.	90.0
911.	911.	113.6	131.4	5060.	126.64	9511.	90.9
747.	747.	114.8	110.7	5010.	105.60	7418.	91.4
613.	613.	115.7	92.1	4996.	87.63	5958.	91.6
503.	503.	116.5	76.3	4983.	72.41	4930.	91.6
412.	412.	117.1	62.9	4981.	59.69	4135.	91.5
338.	338.	117.6	51.7	4984.	49.06	3556.	91.1
277.	277.	118.1	42.3	4987.	40.15	3157.	90.5
227.	227.	118.4	34.4	4990.	32.74	2880.	89.5
186.	186.	118.7	27.9	4995.	26.57	2687.	88.1
153.	153.	118.9	22.5	5004.	21.46	2553.	86.2
125.	125.	119.1	18.1	5011.	17.24	2459.	83.9
103.	103.	119.3	14.4	5017.	13.74	2392.	81.1
84.	84.	119.4	11.4	5024.	10.87	2344.	77.6
69.	69.	119.5	8.9	5030.	8.49	2310.	73.3
57.	57.	119.6	6.8	5035.	6.54	2285.	68.1
46.	46.	119.7	5.1	5039.	4.93	2267.	61.9
38.	38.	119.7	3.8	5043.	3.61	2253.	54.5
31.	31.	119.8	2.6	5046.	2.53	2243.	45.7
26.	26.	119.8	1.7	5048.	1.64	2236.	35.3
21.	21.	119.9	.9	5050.	.90	2230.	23.2

FIELD DATA(SPD# 5)

RSH=.4360E+00 RSHD=.0000E+00 SEV=.1200E+02 SHUNT TURNS = 65.00
RSE=.0000E+00 RS =.0000E+00 RD =.0000E+00 SERIES TURNS= .00

FOR IA) 468.750
BRUSH DROP=1.40+ .00064*IA

FOR IA (= 468.750:
BRUSH DROP= .00363*IA

MOTOR CHARACTERISTIC DATA

IB	IA	VM	TORQ	RPM	HP	LOSSES	EFF
8918.	8918.	57.6	1156.1	0.	.00	586027.	.0
4459.	4459.	88.8	372.9	4769.	338.78	143595.	63.8
3656.	3656.	94.4	301.3	5846.	335.51	95309.	72.4
2998.	2998.	99.0	259.0	6298.	310.67	65515.	78.0
2459.	2459.	102.8	227.9	6396.	277.57	46055.	81.8
2016.	2016.	105.9	201.1	6340.	242.83	32713.	84.7
1653.	1653.	108.4	178.8	6145.	209.30	23494.	86.9
1356.	1356.	110.5	157.7	5937.	178.36	17124.	88.6
1112.	1112.	112.2	137.9	5734.	150.67	12708.	89.8
911.	911.	113.6	120.5	5510.	126.42	9620.	90.7
747.	747.	114.8	101.8	5435.	105.40	7507.	91.3
613.	613.	115.7	84.7	5420.	87.43	6047.	91.5
503.	503.	116.5	70.3	5394.	72.22	5012.	91.5
412.	412.	117.1	58.1	5381.	59.52	4211.	91.3
338.	338.	117.6	47.7	5377.	48.88	3628.	91.0
277.	277.	118.1	39.1	5373.	39.99	3224.	90.2
227.	227.	118.4	31.8	5379.	32.57	2947.	89.2
186.	186.	118.7	25.7	5386.	26.40	2755.	87.7
153.	153.	118.9	20.7	5394.	21.29	2620.	85.8
125.	125.	119.1	16.6	5403.	17.07	2527.	83.4
103.	103.	119.3	13.2	5411.	13.58	2460.	80.5
84.	34.	119.4	10.4	5417.	10.70	2412.	76.8
69.	69.	119.5	8.1	5424.	8.32	2378.	72.3
57.	57.	119.6	6.2	5429.	6.37	2354.	66.9

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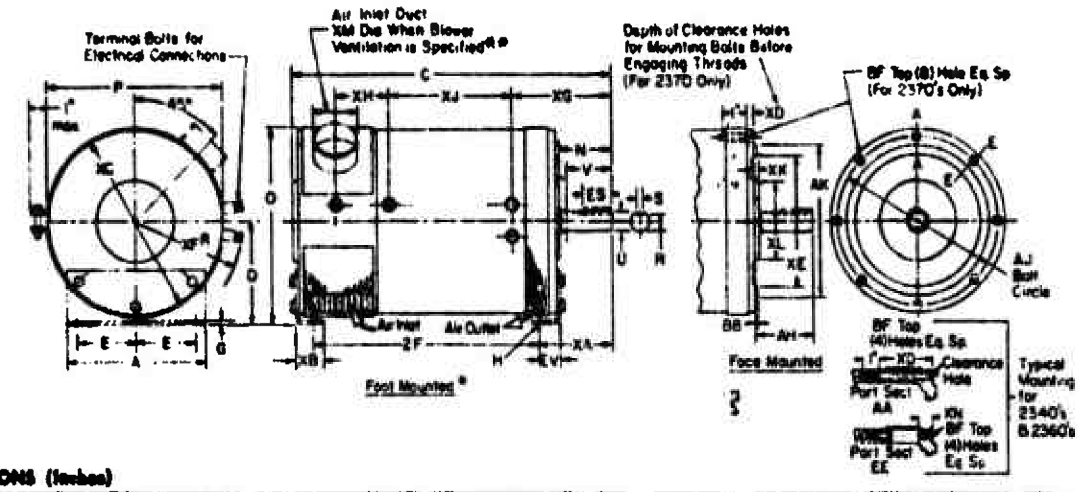
**SCREEN CONTENTS @:TUE, OCT 26, 1982, 5:24 PM

APPEDNIX E

GENERAL ELECTRIC MOTOR DIMENSIONS

DIMENSIONS: Open or Separately Ventilated Motors



DIMENSIONS (Inches)

FRAME SIZE	APPROX NET WT IN LB	A	C	D	E	2F	G	H	N	O	P	R	S	U†	V‡	AH	AJ	AK	BB	BF TAP	ES	EV	XA	XB	XC	XD	XE	XF	XG	XH	XJ	XK	XL	XM	XN
2344	150	8.25	18.53	5.10	2.00	12.12	.18	.44	2.31	9.81	8.00	.986 .871	.25	1.125	2.00	3.06	8.38	7.500 7.457	.12	.3125-24 UNF	1.50	1.12	4.00	1.25	6.35	1.88	6.00	5.00	5.56	5.00	7.12	.52	4.35	2.00	.81
2348	180		20.00			16.62																									8.82				
2364	220	8.50	20.00	6.12	3.50	15.12	.18	.44	2.81	11.84	11.56	1.201 1.186	.21	1.375	2.50	2.81	10.68	8.750 8.747	.16	.375-24 UNF	1.00	.56	2.50	1.50	11.62	2.21	8.88	7.00	2.29	2.00	8.50	-	6.00	5.50	.44
2365	255		21.21			16.44																									8.81				
2368	290		22.00			18.12																									11.50			•	
2374	407		26.56			15.29																									10.88				
2376	445	10.00	26.06	7.50	6.25	15.78	.30	.53	3.21	16.22	13.32	1.416 1.401	.38	1.625	3.00	2.30	15.38	10.750 10.765	.15	.500-20 UNF	2.38	1.50	6.75	3.25	15.50	.61	8.16	7.08	7.52	3.00	12.38	.16	5.00	5.00	..
2378	480		30.06			21.75																									16.28				

* Feet are bolted on type
Machine can be furnished with or without feet. When feet are specified, they can be turned inward or outward.

** For blower ventilation bottom half cover is solid
For open fan-cooled ventilation screen covers top and bottom half will be furnished

† Shaft diameters 1.375 inches and smaller shall come within the limits of +0.0000, -0.0005
Diameter 1.625 inches -0.000, -0.001

Mounting face will be square and rabbet diameter concentric with shaft within 0.004 inch indicator reading. Shaft runout will not exceed 0.002 inch indicator reading.

‡ "V" represents length or straight part of shaft.

APPENDIX F

BENDIX BRUSHLESS GENERATOR, TYPE 30B119-9

Description

Utilizing design features which provide maximum operating reliability with minimum maintenance, the 30B119-9 will produce 300 amps of 30-volt DC electric power when driven at 4000 to 10,000 rpm.

A brushless generator, the 30B119-9 is designed for extended operating service. It is equipped with a fan which supplies cooling air for ground operations and it will accept an air spout for blast air. The generator will provide the outputs shown here:

Altitude Feet	30 Volt DC Output	Air Required
Sea Level	300 amps	Self-Cooled
30,000 to 57,500	400 amps	Blast Air at 11 in., H_2O

Brushless Design

The 30B119-9 has 6 poles with two 3-phase windings connected in wye, and separated by 30 electrical degrees to produce 12-phase commutation of twelve output diodes. The diodes are connected in two full-wave bridges to produce the DC output. No interphase transformer is used in the circuit.

Build-up excitation is provided to the generator exciter field through "residual magnetism" inherent in the generator. When the generator begins to produce its rated output, a portion of this output is used to supply the exciter field.

A small current transformer winding brought out through a rectifier bridge to the (E-) and (D) terminals provides an equalizing voltage for parallel generator operation.

Curvic Drive Spline

The generator is equipped with a curvic drive spline which will accommodate a polyimide spline sleeve with a low coefficient of friction. The sleeve eliminates the metal to metal contact between drive members and smooths driving operations.

Electronic Components 100 Percent Tested

All of the diodes and rectifiers used in the generator undergo audit procedures and 100 percent testing, including soak/bake cycles at hot and cold temperatures.

These components are mounted on an extruded aluminum heat sink which provides efficient transfer of dissipated heat to the cooling air stream.

Solid Epoxy Insulating Material

The generator windings are assembled and held together with welded stainless steel bands. The windings are insulated with 100 percent solid epoxy material which not only provides resistance to hydraulic fluids, fuels, and other solvents found in aircraft environments, but also provides the best possible heat transfer from the inner portion of the assembly.

Generator Control Unit

Bendix 25B12-3 Generator Control Unit is recommended for use with the 30B119-9. This GCU provides voltage regulation and over-voltage, and flywheel diode protection; it will annunciate faults and detects failed diodes in the generator. The 25B12-3 is described in Specification Sheet 79-180.

Design Features

- Brushless design provides long life and high MTBF—practically eliminates maintenance and overhaul.

- Unit delivers full output at sea level and high altitudes—efficient fan supplies cooling air for ground operations and does not impair flow of blast air at higher altitudes.

- Auxiliary bearing system takes over rotor load when main bearings show signs of malfunctioning.

- Curvic drive spline with polyimide spline sleeve eliminates metal-to-metal contact.

Specifications

Nominal Output—30 Volts, 300 Amperes

Speed Range—4,000 to 10,000 RPM

Mounting Flange—Conforms with AND 10262, Type X11A

Spline & Adapter—Per MS 14169, Basic Size ¾-inch

Weight—See Outline Drawing

Auxiliary Bearing System

A unique "bearing-failure sensing and auxiliary bearing system" is designed into the generator. The system detects main bearing failure and provides a means to prevent generator damage in the event of a bearing failure.

The bearing failure sensing device and auxiliary bearing system consists of a small auxiliary bearing mounted on the generator shaft directly adjacent to the bearings at each end of the generator, together with insulated sensing circuits installed in the outer race support housing. Radial clearance of approximately .0025 inches is provided between the outer race of the auxiliary bearing and its support surface so that in operation, the auxiliary bearing, as a unit, turns with the shaft and does not contact the stationary support. When the main bearings begin to wear or fail in any manner such that the shaft becomes displaced from its normal rotational center by .0025 inches, the outer race of the auxiliary bearing will contact its stationary support surface. In doing so, the outer race of the bearing bridges the gap between the insulated detector ring and the adjacent steel surface of the support. This grounds the detector circuit thus closing an indicator light circuit and alerting the pilot to the fact that a main generator bearing is in process of failing. The sketch shows the arrangement of installing the detector circuit in the stationary outer race support.

The sensing circuit consists of a low-carbon steel punched ring installed in the outer race bearing support and insulated with Melamine glass washers and rings. A steel ring is shrunk into the main stationary ring and pressed firmly against the insulated detector ring assembly with appropriate staking at the outer edge to assure positive retention of the assembled parts.

The auxiliary bearing is an extremely lightweight assembly with a 25-millimeter bore, an OD of 1.653 inches and a width of .354 inches. It is temperature stabilized, equipped with Viton seals and greased with DuPont Krytox AC high temperature grease. The combined weight of the auxiliary bearing' outer race support, indicator circuit and connecting leads does not exceed .25 lb per generator.

Advantages of the System

a. Detection of a main bearing failure is indicated at an early stage.

b. The system prevents disintegration of the main bearing and supports the rotor, thus, preventing the rotor rubbing the stator with resultant major damage.

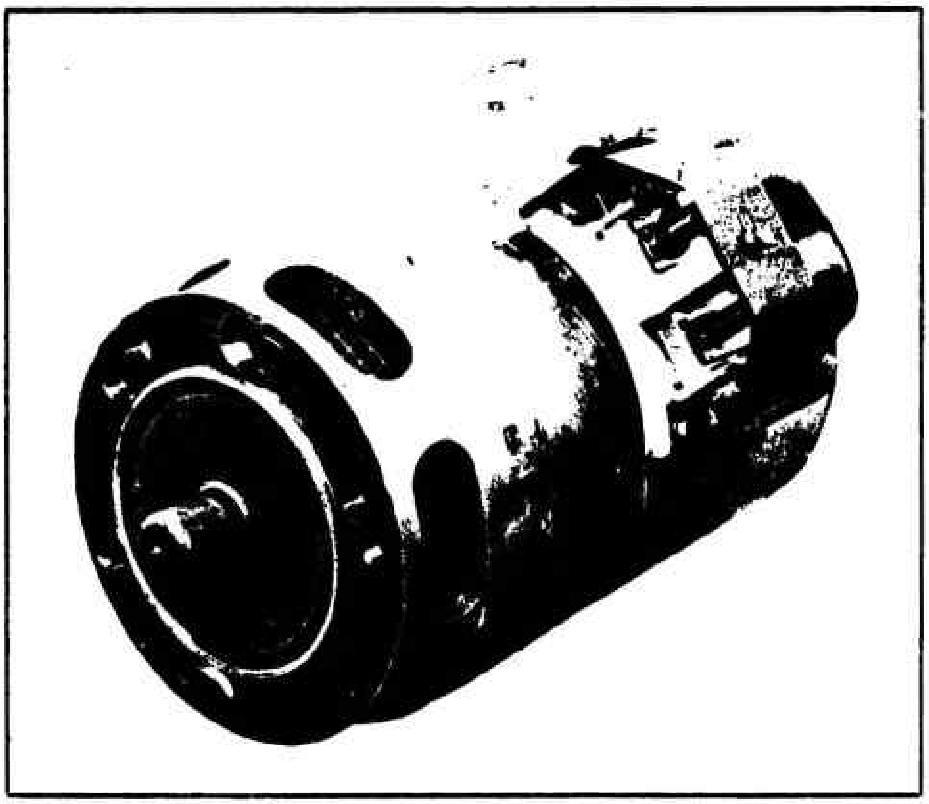
c. The system permits sufficient time for the pilot to take corrective action, de-energizing the generator and permits continued operation of the aircraft engine and/or the constant speed drive.

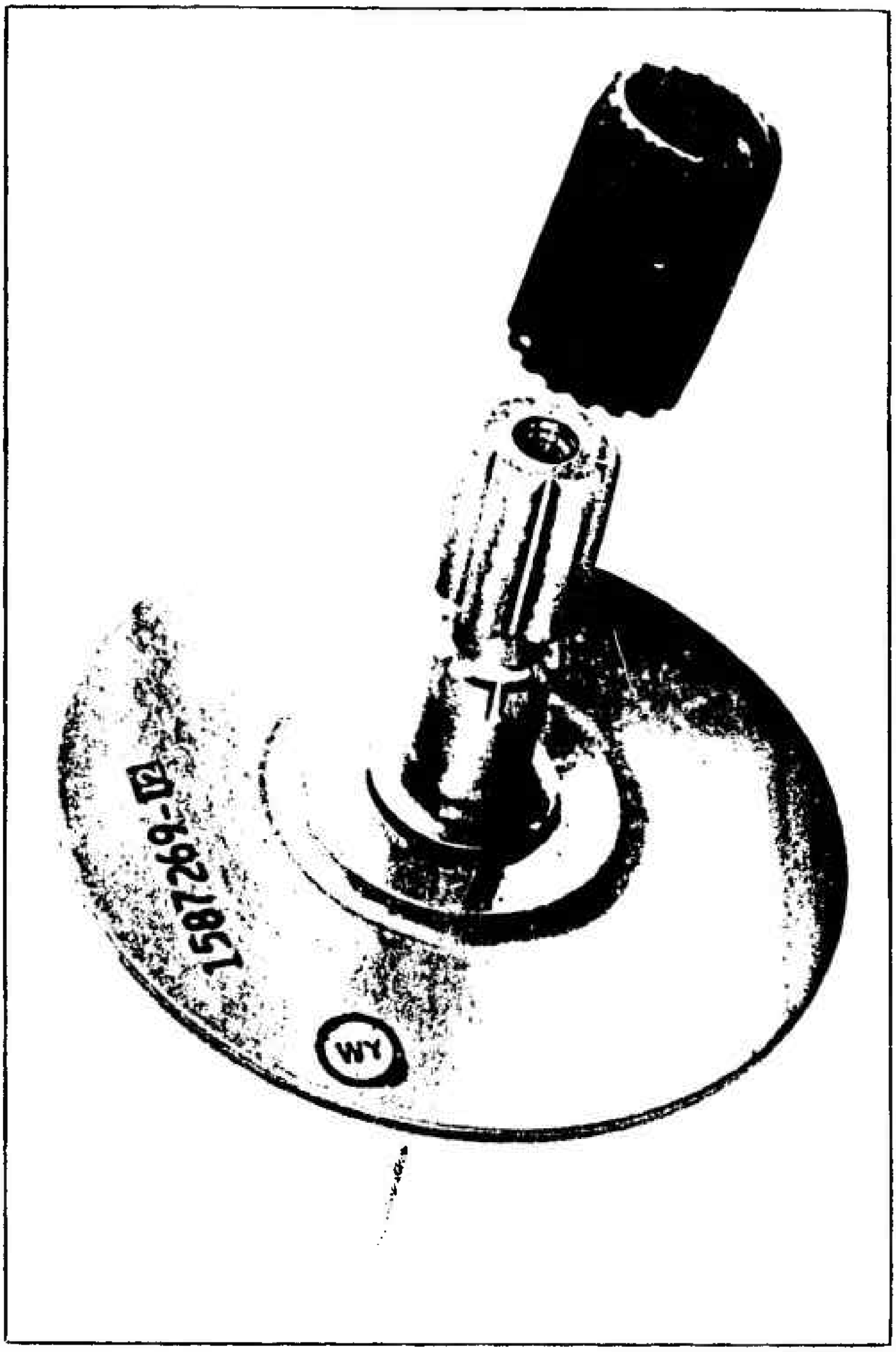
d. The system permits re-energizing the generator in the event of emergency and continued use of the generator on the auxiliary bearing.

e. The system provides a means whereby the generators can be operated "on condition" rather than on a scheduled overhaul basis.

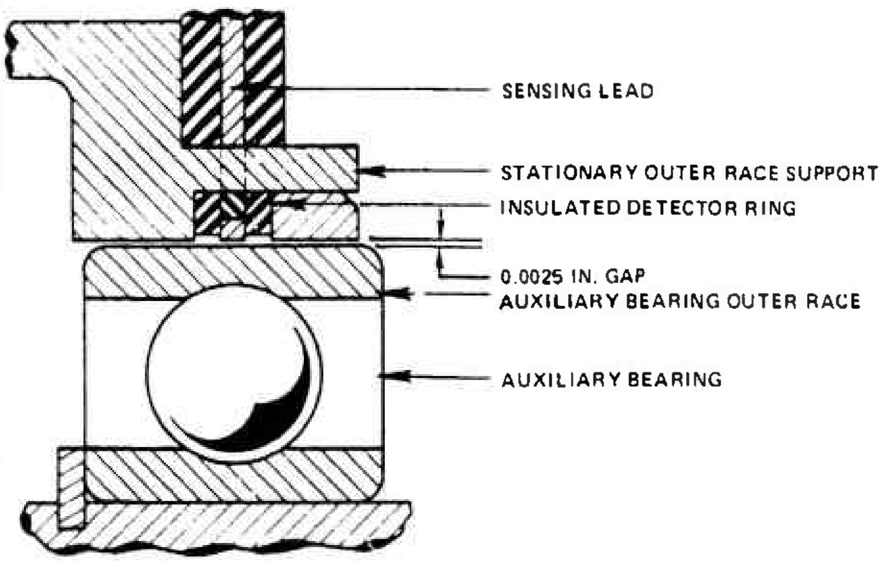
f. An analysis of the cost per operating hour indicates that a reduction in cost to one-third (two-thirds reduction) can be obtained by the use of the Bearing Failure Sensing and Auxiliary Bearing, primarily in the reduction of scheduled overhauls and in the reduction in damage when generator bearings fail.

30B119-9
Brushless DC Generator, 300 Amps.

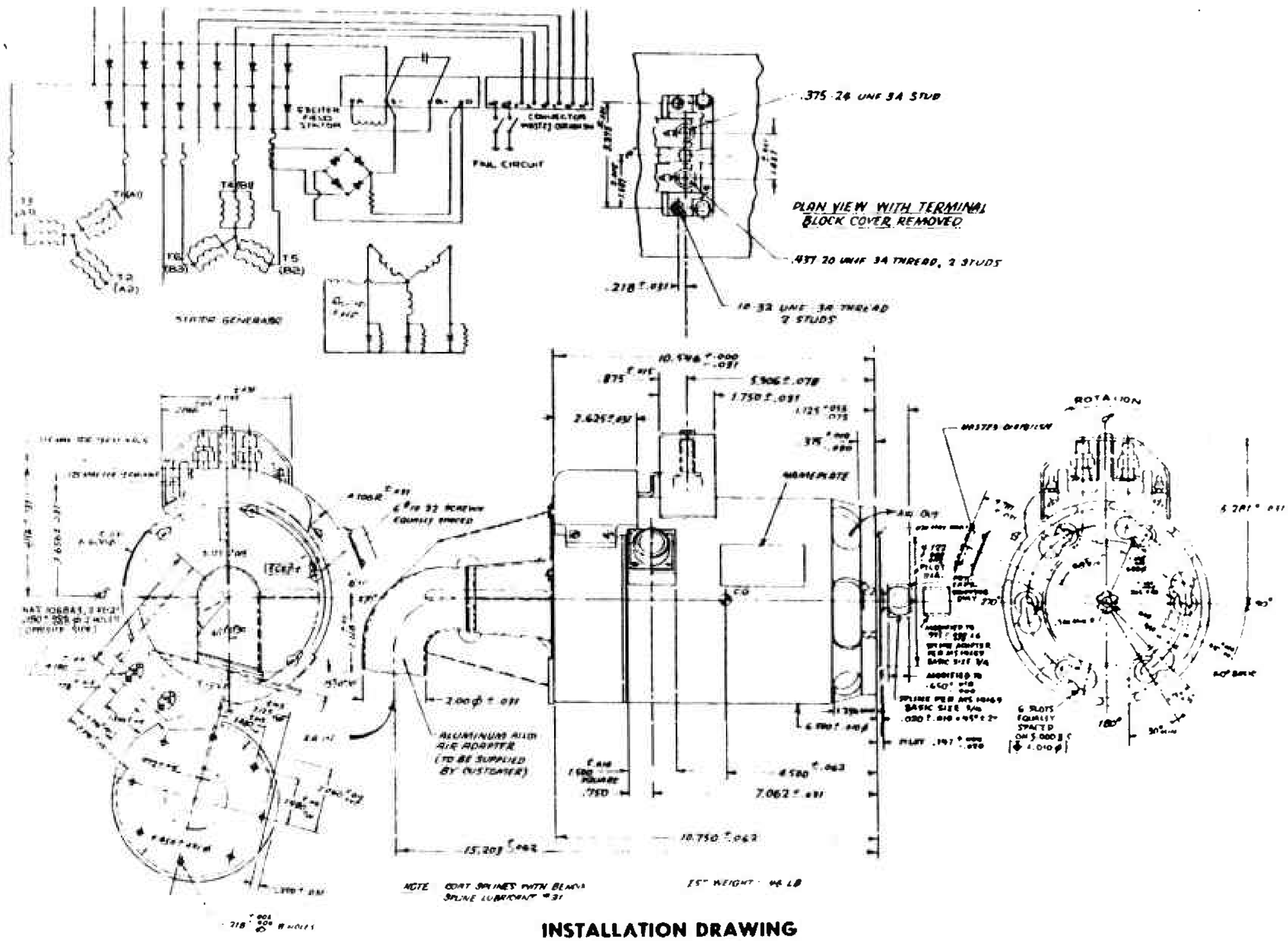




The generator is equipped with a curvic drive spline which will accomodate a polyimide spline sleeve with a low coefficient of friction. The sleeve eliminates the metal to metal contact between drive members and smooths driving operations.



AUXILIARY BEARING AND DETECTOR CIRCUIT

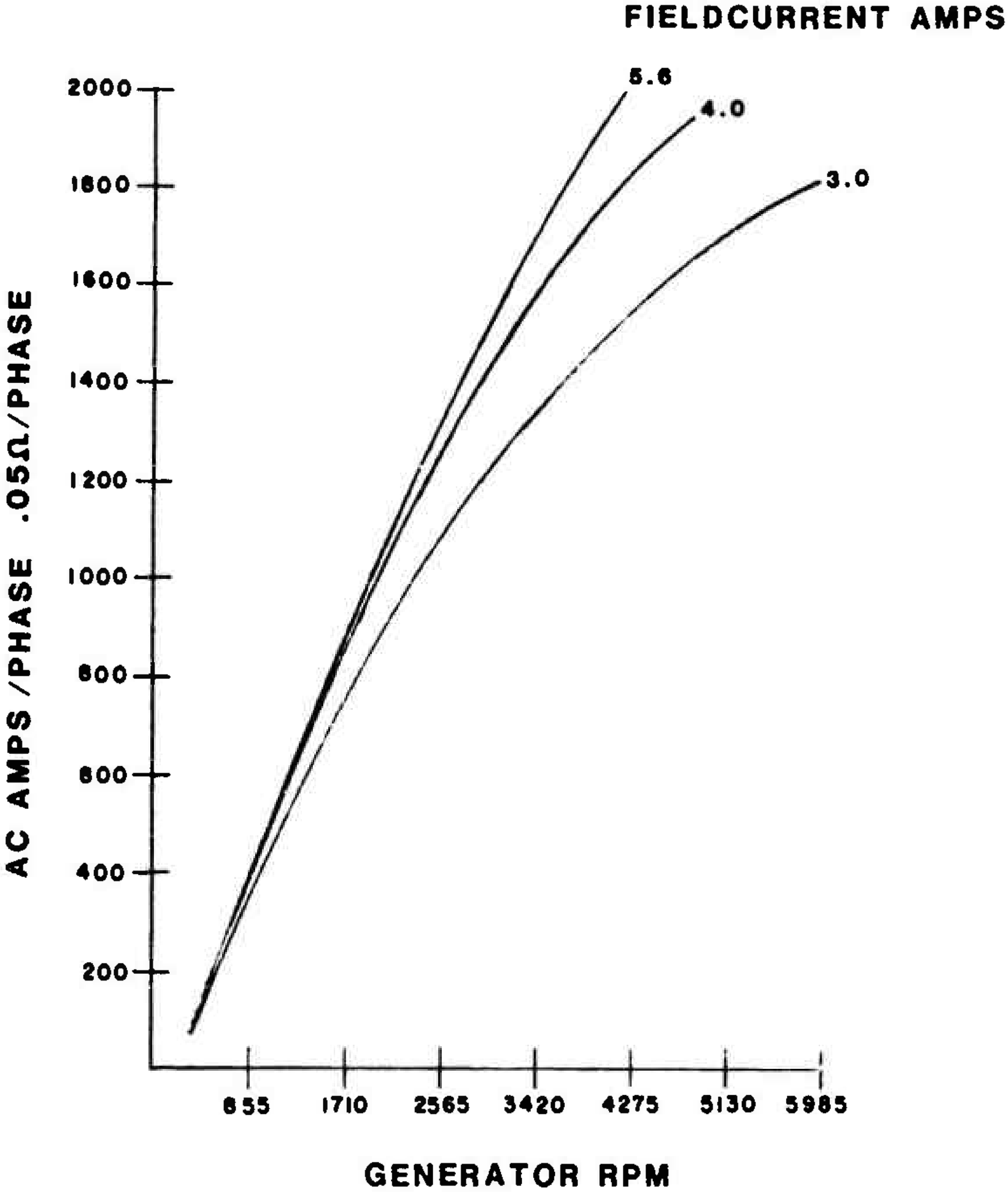


INSTALLATION DRAWING
30B119-9 D.C. GENERATOR

APPENDIX G

LOW-SPEED, HIGH-CURRENT TEST OF WESTINGHOUSE ALTERNATOR

LOW SPEED HIGH CURRENT TEST
WESTINGHOUSE 500KVA 400HZ ALTERNATOR



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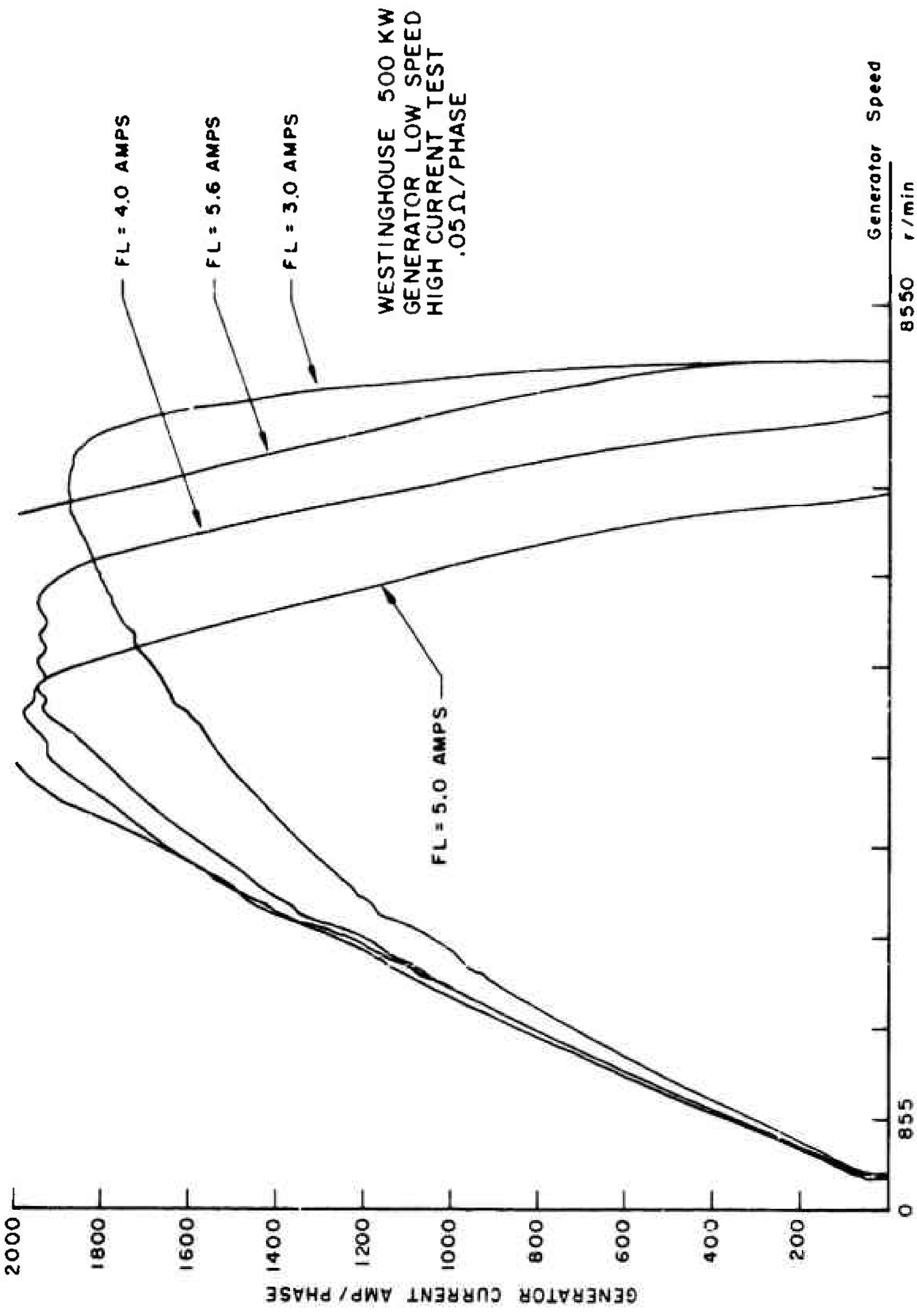

WESTINGHOUSE 500 KW
GENERATOR LOW SPEED
HIGH CURRENT TEST
.05Ω/PHASE
FL = 4.0 AMPS
FL = 5.6 AMPS
FL = 3.0 AMPS
FL = 5.0 AMPS
Generator Speed
r/min
0
855
8550
2000
1800
1600
1400
1200
1000
800
600
400
200
GENERATOR CURRENT AMP/PHASE

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